Engineering Library

ENGINEERING

GENERAL LIBRARY
APR 21 1919
UNIV. OF MICH.

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C. 2

VOL. CVII.—No. 2777.] *LONDON: FRIDAY, MARCH 21, 1919.* [*Registered at the General Post Office as a Newspaper.*] PRICE 9d. BY INLAND POST ... 11d.

Aveling & Porter, Ltd.,
ROCHESTER, KENT,
and 72, CANNON STREET, LONDON.
STEAM ROLLERS. ROAD LOCOMOTIVES.
STEAM CULTIVATING MACHINERY.
STEAM WAGONS. TRACTORS.
CEMENT-MAKING MACHINERY. 6903

A. G. Mumford, Ltd.,
CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See Advertisement, page 33, last week.
PATENT WATER-TUBE BOILERS.
AUTOMATIC FEED REGULATORS
And Auxiliary Machinery as supplied to the Admiralty. 3179

John H. Wilson & Co., Ltd.
Birkenhead.
See Illustrated Advertisement
Page 122, March 14.

Locomotive Shunting Cranes

Steam and Electric Cranes,
EXCAVATORS, CRANE-NAVVIES, GRABS,
CONCRETE-MIXERS.
SHIPS WINDLASSES, WINCHES, and
DECK MACHINERY.
6770
LISTS OF STANDARD SIZES ON APPLICATION.
London Office
15, VICTORIA STREET, S.W. 1.

Ball Bearings
Always British. Large Sizes.
BLACKSTONE BALL BEARING CO.,
London Office:—304, High Holborn, W.C. 1.
For Illustrated Advertisement, see page 6. 7356

Petter Oil Engines.
Manufactured by 7191
PETTERS LIMITED, Engineers, Yeovil.
See our Illustrated Advt. every alternate week.

Craig & Donald, Ltd., Machine
TOOL MAKERS, JOHNSTONE, near Glasgow.
For class of Machine Tools see our Illustrated Advertisement every alternate week. 1356

Electric Lifts
(UP TO 35 TONS.)
S. H. HEYWOOD & CO., LTD.,
REDDISH. 7182

Steam Hammers (with or without guides). Hand-worked or self-acting TOOLS for SHIPBUILDERS & BOILERMAKERS.
DAVIS & PRIMROSE, LIMITED, LEITH, EDINBURGH. 7361

Brett's Patent Lifter Co.
LIMITED.
Hammers, Presses, Furnaces,
COVENTRY. 610

Bever, Dorling & Co., Ltd.,
BRADFORD.
HIGH-CLASS ENGINES FOR ALL PURPOSES,
also WINDING, HAULING, AIR COMPRESSING
and PUMPING ENGINES. 1866

Cranes.—Electric, Steam,
HYDRAULIC and HAND,
of all types and sizes
GEORGE RUSSELL & CO., LTD.,
Motherwell, near Glasgow. 7364
Telegrams—"Cylinders," Birmingham.

Weldless-Steel Tubes
for Water-tube Boilers, Superheaters,
Shafting, Hydraulic Work, Boring Rods, &c.
TUBES LIMITED, BIRMINGHAM. 8179

Yarrow & Co., Ltd.,
SHIPBUILDERS AND ENGINEERS,
GLASGOW.
SPEEDS UP TO 45 MILES AN HOUR.
PADDLE OR SCREW STEAMERS OF
EXCEPTIONAL SHALLOW DRAUGHT.

Repairs on Pacific Coast
by YARROWS, LIMITED, Victoria, British Columbia. 6876
SHIPBUILDERS, SHIP REPAIRERS AND ENGINEERS.

Campbells & Hunter, Ltd.
SPECIALISTS IN
Drillers & Boring Machinery
for Engine Works and Boiler Shops.
DOLPHIN FOUNDRY, LEEDS. 4647

Yachts, Launches or Barges
Built complete with Steam, Oil or Petrol Motors; or Machinery supplied. Od 3531
VOSPER & CO., LTD., BROAD STREET, PORTSMOUTH.

Cochran MULTITUBULAR AND CROSS-TUBE TYPES.
Boilers.
See page 121, March 14. 7253

Electric Cranes.
1182
S. H. HEYWOOD & CO., LTD.,
REDDISH.

FOR
Drop Forgings
write
CARTSHERRIE ENGINEERING & FORGE CO.,
50, Wellington Street, Glasgow. 6931

Tank Locomotives
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO., LTD.,
ENGINEERS, NEWCASTLE-ON-TYNE. 7260

R. Dempster & Sons, Ltd.,
ELLAND, YORKS. 6812

Telpherage & Conveying Plants
See Advertisement page 23, March 14.

Excavators.
FROM 30 TO 600 YARDS PER HOUR.
D. Whitaker,
1, UNION STREET,
LEICESTER. 6869

AERIAL ROPEWAYS, CABLEWAYS, CRANES.
Steel Castings.
See displayed advertisement every alternate week.
JOHN M. HENDERSON & CO., ABERDEEN.

"Spencer-Hopwood" Patent Boilers.
Sole Makers:
W. H. SPENCER & CO., HITCHIN, HERTS.
See page 15, March 14. 7424

Henry Wells Oil Co.,
11, HAYMARKET,
London, S.W. 1.

"Aptol" Lubricants.
WORKS: SALFORD, MANCHESTER. 7184

Iron and Steel
Tubes and Fittings.
6920
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 94, Robertson Street, Glasgow.
See Advertisement page 93.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS,
CALORIFIERS, EVAPORATORS, } HOW'S PATENTS.
CONDENSERS, AIR HEATERS,
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 5733

Tubes and Fittings,
IRON AND STEEL.
Stewarts and Lloyd's, Ltd.,
41, OSWALD ST., GLASGOW.
BROAD STREET CHAMBERS, BIRMINGHAM;
and LONDON OFFICE—
WINCHESTER HOUSE, OLD BROAD STREET, E.C.
LONDON WAREHOUSE—167, UPR. THAMES ST., E.C.
LIVERPOOL WAREHOUSE—63, PARADISE ST.
MANCHESTER WAREHOUSE—34, DEANSGATE.
CARDIFF WAREHOUSE—132, BUTE ST.
BIRMINGHAM WAREHOUSES—NILE STREET, SHERPCOTE STREET, and 10, COLEHILL STREET.
See Advertisement page 29. 7366

Die Finished Castings
ensure rapid production and reduce prime cost by eliminating machining operations. Write for illustrations to AERATORS LTD., Edmonton, London, N. 18.

FLEXIBLE, NON-RUSTING
Metallic Hose-Covering
to protect & strengthen tubing for all pressures and purposes. As supplied for H.M. Govt.—AERATORS LTD., Edmonton, London, N. 18.

R. Heber, Radford, Son & Squire,
ENGINEERING, IRON AND STEEL WORKS
Valuers.
CONSULTING ENGINEERS, REFEREES, AND ARBITRATORS.
Established over 50 years. 7186
16, ST. JAMES ROW, SHEFFIELD.
Telegrams: "Radford, Sheffield." Telephone: 426.

Locomotive Traversers
(ELECTRIC).
7182
S. H. HEYWOOD & CO., LTD.,
REDDISH.
GOLD MEDAL—ISTEDDFOD EXHIBITION AWARDED.

Duckham's Patent Suspended
WEIGHING MACHINES.—EAST FERRY ROAD ENGINEERING WORKS COMPANY, LTD., LONDON, E.—Hydraulic Cranes, Grain Elevators, &c.
See Illus. Advt. last week, page 15. 7046

Patent
See's Hydro-Pneumatic Ash Ejector.
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20ft. clear of vessel.—Apply, F. J. TRIWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4835

Separators
— FOR —
EXHAUST STEAM TURBINES COMPRESSED AIR, &c.
STEAM DRYERS.
METALLIC PACKINGS.
Princeps & Co.,
SHEFFIELD. 6086

New Chicago Automatics.
Three Sizes, Delivery from Stock.
NEW CAPSTANS, 1¼ in. through the wire feed.
JOHN MACNAE, MARY STREET, HYDE.
Tel. No.: 78 Hyde 6074

Rubber MANUFACTURERS
Packings "Beclstone" "Bluestone"
GUTTA PERCHA & RUBBER, LIMITED,
Toronto Canada. 6702

CHANTIERS & ATELIERS
Augustin-Normand
67, rue de Perrey—LE HAVRE
(France).
3890
Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

Yarrow Patent
Water-Tube Boilers.
6094
MESSRS. YARROW & CO., UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

John Bellamy Limited,
MILLWALL, LONDON, E.
GENERAL CONSTRUCTIONAL ENGINEERS. 1310
Boilers, Tanks & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

RAILWAY AND TRAMWAY ROLLING STOCK.
Hurst, Nelson & Co., Ltd.
THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3503

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 54, March 14. 7366

Matthew Paul & Co., Ltd.
LEVENFORD WORKS, Dumbarton.
See Full Page Advt., page 78, March 7.

Taylor & Challen
Presses.
8130
TAYLOR & CHALLEN, LD., Engineers, BIRMINGHAM.
See Full Page Advertisement, March 7.

Steel Castings.
THOMAS SUMMERSON & SONS, LTD.,
DARLINGTON. 6924

Electric Transporters,
S. H. HEYWOOD & CO., LTD., 7183
REDDISH.

P. & W. MacLellan, Limited,
CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF
RAILWAY CARRIAGES AND WAGONS
OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
Chief Offices: 120, Trongate, GLASGOW. Od 3547
Registered Offices: 106A, Cannon St., London, E.C.

Aluminium

INGOTS	for JIGS & PULLEYS.
SHEETS	for CHEMICAL VESSELS.
WIRE	for ELECTRIC CABLES.
SECTIONS	for MOTOR BODYWORK.
TUBE	for TYRE HANDRAILS.
POWDER	for PAINT, &c., &c.

7360
DESCRIPTIVE LEAFLETS
free from
THE BRITISH ALUMINIUM CO., LTD.,
109, Queen Victoria St., London, E.C. 4.

B. & S. Massey, Ltd., MANCHESTER.
Steam Hammers,
Power Hammers,
Drop Stamps,
Band Saws. 1290
QUICK DELIVERY. LARGE STOCK.

The Manchester Steam Users' ASSOCIATION.
For the Prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by Sir WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 7479

A.M.I.C.E. and A.M.I.M.E. Tuition. Also Postal Courses in Mechanical Engineering, Aircraft Design and Mathematics.—PENNINGTONS, 284, Oxford Road, Manchester.

Inst. C.E., I. Mech. E., B.Sc., and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—38, Victoria St., Westminster, S.W. 7438

Inst. C.E., Inst. Mech. E., and all Engineering Exams. Correspondence coaching by practical engineers. I.C.S. successes 265 out of 293. Two Bayliss Prizes, "Proxime Accessit." Special features for foreign candidates. Write for booklet, &c.—Address, 7494, Offices of ENGINEERING.

Reinforced Concrete.—Mr. A. J. B. ATKINSON, Assoc.M.Inst.C.E. and Mr. C. PROBERT, Assoc.M.Inst.C.E. conduct a CORRESPONDENCE COURSE of TUITION in the THEORY of REINFORCED CONCRETE CONSTRUCTION. For full particulars and synopsis of lectures write to Messrs. ATKINSON & PROBERT, 40, High Street, Newcastle, Staffs. T 479

TENDERS.

SHOEBURYNESS URBAN DISTRICT COUNCIL.

The Council have for Disposal TWO "Crossleys" (35 B.HP. maximum) GAS ENGINES, Bunsen Ignition, in excellent condition. Can be seen running at the Council's Waterworks, Shoeburyness.
Tenders to be sent to me by Four o'clock, on Tuesday, 1st April.
The Council do not bind themselves to accept the highest or any Tender.
FREDERIC GREGSON,
Southend-on-Sea, Clerk.
8th March, 1919. T 347

TENDERS FOR BOUNDARY PILLARS REQUIRED BY THE SURVEY IN EGYPT IN 1919.

Tenders for the Supply of 250,000 OLD RAILS, two meters long, will be received at the Offices of Sir A. L. WEBB, K.C.M.G., Inspecting Engineer to the Egyptian and Sudanese Governments, Queen Anne's Chambers, Broadway, Westminster, S.W. 1., up to noon on 30th April, 1919.
Copy of Specification and Conditions of Tender may be seen at the above offices. T 606

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the following STORES, namely:—

	Fee for Specification.
Steel Rails and Fishplates	£1
Steel Fishbolts, &c.	10/-
Tie Bars, Bits and Cutters	10/-
Cranked Fishplates	5/-
Wheels and Axles and Steel Axles ...	£1
Helical and Volute Springs ...	£1
Tyre Retaining Rings and Bolts ...	£1
Galvanised Corrugated Sheets... ...	10/-

Specifications and Forms of Tender may be obtained at this Office on payment of the fee for the Specification, which payment will not be returned.
Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Steel Rails and Fishplates," or as the case may be, not later than 11 o'clock a.m., on TUESDAY, the 1st APRIL, 1919.
The Directors do not bind themselves to accept the lowest or any Tender.
R. H. WALPOLE,
Secretary.
Company's Offices,
48, Copthall Avenue, E.C.,
London.
10th March, 1919. T 635

APPOINTMENTS OPEN.

ROYAL SIAMESE STATE RAILWAYS.

Applications are Invited for the POST of ASSISTANT CHIEF MECHANICAL ENGINEER.
Applicants must have had good technical and general education, and mechanical Engineering, including the building, repair and maintenance of Locomotives, carriage and wagons. Drawing Office and Workshop management. Age not over 35. The engagement will be for three years. Salary—approximately 13 ticals = £1—1,000 ticals per month rising to 1,100 ticals per month, with travelling and field allowances.
Apply by letter to Messrs. C. P. SANDBERG, 70, Victoria Street, Westminster, S.W. 1, giving age, full particulars of education and experience, and copies of testimonials. T 490

ROYAL SIAMESE STATE RAILWAYS.

Applications are Invited for the POSTS of WORKSHOP MECHANICAL FOREMEN.
Applicants must be highly trained mechanics, well up in Locomotive building and repair, boiler, smith, foundry and spring work, and oxy-acetylene welding; they must also be capable of successfully controlling men; the engagement will be for three years; salary 350 ticals per month rising to 400 ticals per month—approximately 13 ticals = £1—with travelling and field allowances.
Apply letter to Messrs. C. P. SANDBERG, 70, Victoria Street, Westminster, S.W. 1, stating age, full particulars of experience, and enclosing copies of testimonials. T 491

COUNTY BOROUGH OF HUDDERSFIELD TECHNICAL COLLEGE.

PRINCIPAL—J. P. HUDSON, M.A., B.Sc.

Applications are Invited for the POSITION of LECTURER in Mechanical Engineering. Commencing salary £300.
Further particulars on application to—
T. THORP, Secretary.
T 229

LEEDS TECHNICAL SCHOOL.

DEPARTMENT OF MECHANICAL ENGINEERING.

Lecturer Required, to Give Theoretical and Laboratory Instruction in Engineering Subjects, preferably with University or equivalent qualifications and experience of modern works methods. Commencing salary from £300 to £300 per annum. Written applications, with copies of testimonials, should be forwarded on or before 31st March, to the undersigned.
JAMES GRAHAM
Education Offices, Director of Education.
Leeds, March, 1919. T 404

Live Progress Man Required, for large repetition factory in Essex; previous experience essential; sound practical experience would be an assist.—Address, stating experience, age, and salary required, T 387, Offices of ENGINEERING.

Wanted, for Aeroplane Factory on the Continent, competent CHIEF ENGINEER, who must have received a thoroughly sound engineering training, and have had some years' experience with the design and production of the best British aeroplanes.—Apply, in the first place, stating age, experience, knowledge of Continental languages (if any) and approximate salary required, to BOX E. M. 12, care of W. H. SMITH AND SON, 55, Fetter Lane, London, E.C. 4. T 497

General Manager Required for a General Engineering and Ship Repairing Works, comprising: engine works, boiler works, iron and brass foundries, ship smiths, tin plate workers and coppersmiths, brass finishers and turners, pattern makers, ship carpenters, mast and block makers, and iron ship repairing works.
The Candidate will be expected to take full responsibility for the output and control of production staffs. Must be experienced in up-to-date methods of production and repairs.
Applications (which will be regarded as confidential), must state age, salary required, and previous experience, and forwarded by registered letter not later than April 4th, addressed as follows:
The SECRETARY,
Gt. Central Co-operative Engineering and Ship Repairing Co., Ltd.,
Fish Docks, Grimsby,
and marked "Application Works Manager."
Applicants should state the earliest date they can take up position after receiving intimation of the appointment. T 510

Works Manager Required, by progressive engineering firm employing about 600 hands. One with experience of agricultural machinery preferred. The position commands a good salary with splendid prospects for one of real ability. Applications will be treated in the strictest confidence and should state age, past experience, present position and employers, salary required and when available.—Address, T 515, Offices of ENGINEERING.

Wanted, an Assistant Chemist for a large engineering works in Luton, must be capable of accurately analysing tool steels, cast irons, &c.—State particulars of training, age and salary required, T 601, Offices of ENGINEERING.

Required, by an English Firm of Manufacturers of Mining Requirements, a GENTLEMAN as manager of their Indian Office: he must have good commercial and selling experience, and knowledge of engineering. One with previous Indian experience and a connection amongst the mines and P.W.D. preferred.—Address, in confidence, T 600, Offices of ENGINEERING.

Boiler Shop Works Manager wanted for large up-to-date Marine Boiler Shop on Upper Reaches of Clyde. Applicants must be men of experience and energy, and able to take full control; used to large output and quick production on economical lines. Apply, in confidence, giving full particulars of age, experience, and salary expected.—Address, "BOILER," WM. PORTEOUS AND CO., Advertising Agents, Glasgow T 604

Wanted, Expert Cost Clerk for large steel works in North Midlands, must possess the essential qualifications.—Address, T 543, Offices of ENGINEERING.

Works Manager (Non-Ferrous Alloys) REQUIRED to take entire charge of well-established foundry in the Midlands. Only those with considerable experience in making and casting alloys and with a thorough practical and up-to-date knowledge of foundry practice need apply. Necessary to state age, salary expected, and any other information that will help advertiser to consider application, which will be treated in confidence.—Reply by letter to JENNINGS & SON, Solicitors, 99, Leadenhall Street, E.C. T 634

Commercial Manager.—Owing to extensive reconstruction plans an opportunity presents itself in the office of a non-ferrous metal works in the Midlands, must have a knowledge of general engineering, possess good organising and initiative powers, with ability to generally conduct business. Only those with a thorough knowledge of non-ferrous alloys need apply, with full particulars of past experience, stating age, salary required, and any other information that will assist consideration. All communications will be considered strictly confidential.—Reply by letter to JENNINGS & SONS, Solicitors, 99, Leadenhall Street, E.C. T 663

Wanted, a Costs Clerk, Experienced in best methods of compiling costs in a Foundry and Engineering Works.—Apply, RICHARD NEVILL & CO., LTD., Llanelly. T 574

Wanted, a Manager, to take charge of a Bessemer and Open Hearth Plant in South Wales.—Address, giving full particulars as to age, previous experience and salary, T 213, Offices of ENGINEERING.

Wanted, Analytical Chemist to take charge of Laboratory in Siemen's Steelworks—Apply, T 567, Offices of ENGINEERING.

Metallurgical Chemist WANTED, a first-class man with practical works experience, for large engineering works. Knowledge of carburising and heat treatment of steel. Analysis of steels, oils and greases.—Address, stating age, experience and references, T 384, Offices of ENGINEERING.

Wanted Immediately, a MECHANIC, experienced in the working and care of Diesel oil engines, to take charge of a water works pumping plant in quiet country district of Norfolk; dwelling house provided until new one is erected on works.—Apply, stating age, experience, wages required, with references and testimonials, to MANAGER, 2, York Road, Great Yarmouth T 363

The English Electric Company INVITE Applications for the Position of WORKS MANAGER at the Coventry Ordnance Works. Experience in the manufacture of Steam Turbines and Heavy Electrical Plant, whilst advantageous, is not necessarily essential. Applications will be treated confidentially and should be addressed to the MANAGING DIRECTOR, COVENTRY ORDNANCE WORKS, at Coventry, the envelopes being marked "W.M." Previous experience and salary required should be stated. T 573

Enamelled & Tinned, Pressed, STAMPED AND MACHINE MADE HOLLOW-WARE TRADE.
A VACANCY OCCURS, consequent upon the death of Works Manager, in a large and up-to-date factory, for a FIRST-CLASS ENGINEER—if with special knowledge of this particular trade, a recommendation. A young, energetic and capable man, who has passed through the works of Taylor and Challen, Bliss & Co., or a similar firm, who has had actual workshop experience, and the installation and erection of new buildings and plant, and is not afraid of work or early hours, preferred. Must be a good organizer with plenty of initiative, and with tact and skill in dealing with male and female workers. Only those with the knowledge, experience and ability to command a good salary need apply.
Applications, which should be by letter only, must give fullest particulars of age, education and experience as tersely as possible.
All communications will be treated as confidential.
Address—
THE WELSH TINPLATE AND METAL STAMPING COMPANY, LTD.,
Llanelly,
South Wales. T 566

CITY OF BRADFORD.

ELECTRICITY DEPARTMENT.

MANAGERIAL ASSISTANT.

Applications are Invited for the POST of MANAGERIAL ASSISTANT in the Electricity Department of the Bradford Corporation.
The person appointed is required to assist the City Electrical Engineer and Manager in all matters appertaining to the managerial side of the Undertaking, and to be responsible to him for the immediate control of the clerical and storekeeping staffs.
Applicants must be well educated, and have received a sound commercial training in some large undertaking or firm, preferably engaged in the business of electricity supply or the manufacture of electrical machinery or apparatus.
The salary attached to the post is £500 per annum.
The successful candidate will be required to devote his whole time to the duties of the office, and to reside within the city.
Canvassing members of the Council will be a disqualification.
Lists of Duties and Forms, on which applications are to be made, may be obtained from MR. THOMAS ROLES, City Electrical Engineer and Manager, Town Hall, Bradford.
Applications, endorsed "Managerial Assistant—Electricity Department," accompanied by copies of not more than three testimonials (which will not be returned), to be sent in time to reach me not later than the first post on Thursday, the 27th March, 1919.
FREDERICK STEVENS,
Town Clerk.
Town Hall, Bradford.
10th March, 1919. T 392

CITY OF BRADFORD.

ELECTRICITY DEPARTMENT.

CHIEF ASSISTANT ELECTRICAL ENGINEER.

Applications are Invited for the POST of CHIEF ASSISTANT ELECTRICAL ENGINEER in the Electricity Department of the Bradford Corporation.
The person appointed is required to assist the City Electrical Engineer and Manager in all engineering matters, but principally in connection with the generation and distribution of electrical energy.
Applicants must have received a sound technical education, and have practical knowledge of the design and operation of electrical generating and converting plant and transmission and distribution systems.
The salary attached to the post is £760 per annum.
The successful candidate will be required to devote his whole time to the duties of the office, and to reside within the city.
Canvassing members of the Council will be a disqualification.
Lists of Duties and Forms, on which applications are to be made, may be obtained from Mr. THOMAS ROLES, City Electrical Engineer and Manager, Town Hall, Bradford.
Applications, endorsed "Chief Assistant Electrical Engineer," accompanied by copies of not more than three testimonials (which will not be returned), to be sent in time to reach me not later than the first post on Thursday, the 27th March, 1919.
FREDERICK STEVENS,
Town Hall, Bradford. Town Clerk.
10th March, 1919. T 392

A Large Firm of Engineers in the Midlands, have an OPENING for a YOUTH of good education as premium pupil, the course to include both works and drawing office.—Address, 4380, Offices of ENGINEERING.

Wanted, an Engineer, to superintend engineering shops in connection with large steel works and collieries in south Wales.—Address, stating age, salary required, T 124, Offices of ENGINEERING.

Assistant Manager Wanted, by Shipbuilders and marine engineers in China, with technical and practical knowledge of modern shipbuilding and marine engineering; experienced in estimating; aged 33 to 40; three years' engagement.—Reply, by letter, detailing experience and salary required, to SHIPBUILDING, care of ADDOTTS, 32, Bastcheap, London, E.C. 3. T 408

Wanted, for a large Marine Engine Works, a fully qualified ASSISTANT WORKS MANAGER. State age and experience.—Address, T 468, Offices of ENGINEERING.

Wanted, Assistant Engineer for Wireless Telegraph Design Department at Portsmouth. Applicants to have engineering degree and training. Salary £300 per year.—Replies to BOX 1774, WILLINGS, 125, Strand, London, W.C. 2. T 436

Assistant Civil Engineer and SURVEYOR REQUIRED for the Harbour Engineer's Department, Colombo Port Commission, Ceylon, for two years' service, with possible extension.
His duties will consist of taking levels and harbour soundings, supervising the work of dredgers, preparing drawings and estimates for new works. He should also have a practical knowledge of building, design and construction, including reinforced concrete work, and must be capable of controlling labour. Salary £500-£25-£600 per annum. Free passages, no free quarters.
Apply at once, by letter, giving age and summary of qualifications and experience, to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, S.W. 1, quoting M/8534. T 434

Quarry Manager Wanted, in connection with harbour works contract in Far East. Must be under 38 years of age and have had previous experience granite quarries or rock excavation. Previous experience abroad a recommendation. Salary about £750 per annum with quarters; three years' engagement; climate not suitable for man who has suffered from shell shock.—Write, BOX Q.M., Messrs. A. W. BROWN, 39, Tothill Street, S.W. 1. T 543

Works Engineer Wanted, capable of taking charge of the general engineering work of a manufacturing plant. Essential to have had experience in stationary power plant and general machine shop practice. Preference given to applicant with experience in refrigeration.—Replies, giving full particulars of qualifications and previous experience, to be addressed to the SECRETARY, KODAK LIMITED, Kingsway, London. T 426

Assistant Sales (Indoor) and ESTIMATING ENGINEER, 25 to 35 years, good correspondent, and possessing shop and commercial experience, electric cranework, Manchester district. Salary and other particulars. Address, T 505, Offices of ENGINEERING.

General Manager (with aid of works manager) WANTED, for engineering works, one well known in the commercial world preferred. Must be persevering and energetic and have a keen business insight into all matters pertaining to a progressive business and capable of corresponding in French. Will pay reasonable and progressive salary to the right man. In reply, state age, salary and experience.—Address, T 561, Offices of ENGINEERING.

Works Manager Wanted, for an engineering works, including foundry and smithy, from 200 to 300 employees in all, making all kinds of lifting tackle, including electric and other cranes. Must be well up in all kinds of engineering, up-to-date methods of production, good organiser. Must be a thoroughly energetic man and first-class timekeeper. Willing to pay a good and progressive wage to first-class man. In reply, state age, wages and experience.—Address, T 562, Offices of ENGINEERING.

Wanted, Assistant Engineer for Punta Arenas, Chile, with experience both theoretical and practical in the laying out of high and low tension three phase distribution for lighting and power, and capable of taking under his charge the conversion of aerial single phase system to underground three phase. State age, experience and salary required.—Address, T 598, Offices of ENGINEERING.

Manager Wanted for an established engineering works near London, making steam road rollers and traction engines, and employing 1000 hands, capable at re-organising repetition work on up-to-date methods.
A well-educated, energetic man, who might qualify for a seat on the Board of Directors.—Address, T 556, Offices of ENGINEERING.

Wanted, a Constructional ENGINEER for India, thoroughly experienced in the construction of iron buildings, &c., with estimating and drawing office experience. Must be unmarried, age not to exceed 30. Commencing salary equivalent to £300 per annum, with good prospects. Five years' agreement.—Write, stating age, full particulars of experience and copies of testimonials, to Z. J. 739, care of DEACON'S, 7, Leadenhall Street, London, E.C. 3. T 577

Wanted Several First-class ENGINEERS who who have had experience in Designing and Instilling factory machinery. Liberal salaries paid to the right men.—Address, stating experience, and salary required, to BOX 36, care of MATHER & CROWTHER, LTD., New Bridge Street, E.C. 4. T 608

ON SOME PRINCIPLES OF MANUFACTURING INTERCHANGEABLE ARTICLES TO LIMIT GAUGES.

By Professor G. GERALD STONEY, F.R.S., and Mr. S. LEES.

A NOTE on "The Errors in Interchangeable Parts," which appeared in ENGINEERING (January 4, 1918, page 18), gives rise to some interesting reflections on the question of fixing limits of accuracy to the manufacture of interchangeable parts of machines. The conclusions which are given below would appear to be important to all manufacturers of interchangeable parts, and may seem somewhat unexpected.

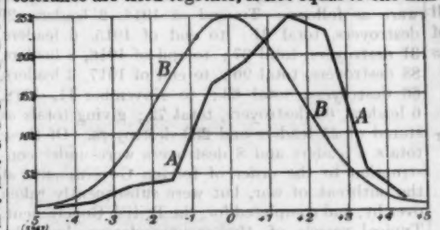
The general object in employing limit gauges is to enable parts of machines to be made interchangeable. Since it is impossible to machine any article to exactly the size required, certain limits of error (called "tolerances") must be specified, which limits may vary according to circumstances. It is important to keep these limits as wide as possible, so as to increase the ease of manufacture and to reduce cost. If any two articles are to be manufactured to fit one another, it is usual to prescribe the theoretical or ideal difference of their fitting dimensions. This difference (called the "allowance") depends on the kind of fit required, *e.g.*, whether force, running, or push fit, &c. The general principles on which the limits of error (or tolerances) for any articles are fixed, are determined by the maximum and minimum allowances that are possible. Thus, two parts of a machine that are to fit together must be neither too tight nor too slack. For instance, in the case of a running fit, the fit must be such that the shaft is not so tight in the hole as to be liable to seize or jamb, whilst it must not be so slack in the hole as to allow undue shake or play. Between these two limits, the shaft will work correctly in the hole. It is necessary, for interchangeability, that the biggest shaft should work in the smallest hole without being unduly tight, and that the smallest shaft should work in the largest hole without being unduly slack. Assuming that the positive and negative tolerances for both shaft and hole are respectively equal to one another, it is clear that twice the sum of the tolerances of shaft and hole must not exceed the difference between the minimum allowance of the tight fit and the maximum allowance of the slack fit.

For instance, if with a 1-in. hole and shaft, and good workmanship, we prescribe tolerances of $\pm$ 6 $\times$ 10^{-4} inches for both shaft and hole, with a running fit having an allowance or mean clearance of 15 $\times$ 10^{-4} in., then we find that the minimum diameter of the shaft is 0·9979 in., the maximum diameter is 0·9991 in.; whilst the minimum diameter of the hole is 0·9994 in. and the maximum 1·0006 in. This means that the amount of play will vary from 3 $\times$ 10^{-4} in. to 27 $\times$ 10^{-4} in. It will thus be seen that to get a reasonably constant fit, means working to very fine limits of accuracy.

In cases of push fits, in order to reduce the cost of production and to enable the limits to be increased, a certain amount of "obstruction" is permitted. With such limits, the smallest hole with the largest shaft will be too tight a fit, whilst the biggest hole with the smallest shaft will be too slack a fit. It is possible to allow of this and yet to obtain interchangeability in practice, because the chance of the smallest hole and the biggest shaft, or, the biggest hole and the smallest shaft, coming together is very remote, and will happen so seldom that the risk can be taken.

Generally speaking, this probability argument can be applied to any kind of fit, and the contention here put forward is that to obtain a given character of fit, much greater tolerances can in practice be allowed than is customary at the present time. That this is so, is well exemplified by the account of the errors in interchangeable parts, which appeared in ENGINEERING (*loc. cit.*). Here, a large number of measurements of crank-pins were made, the tolerance in manufacture being 5 $\times$ 10^{-4} in. The target diagram A given in the Note from ENGINEERING is here reproduced; B is the theoretical diagram assuming the Gauss law of error (see below). From diagram A it will be seen that although the limits of error allowed (*i.e.*, tolerances) were 5 $\times$ 10^{-4} in., yet 90 per cent. of the pins fell within one-half of these limits. If we assume that the tolerances of the holes which the pins had to fit were also 5 $\times$ 10^{-4} in., and the observed errors were the same as for the pins, we should then have, for a running fit with a mean allowance of 13 $\times$ 10^{-4} in., a maximum clearance of 23 $\times$ 10^{-4} in. and a minimum clearance of 3 $\times$ 10^{-4} in. In practice, however, it would be found that about 98 per cent. would have clearances varying from 7 in. to 17 $\times$ 10^{-4} in., with a mean clearance of 12 $\times$ 10^{-4} in., as if the limits or tolerances were only 2·5 $\times$ 10^{-4} in., instead of 5 $\times$ 10^{-4} in. This means a clearance range of about 2·5 to 1 for about 98 per cent. of the pins and holes, and a much greater ratio for the remaining 2 per cent. of the fits. If, then, it is allowable that 2 per cent. of the fits may be adjusted afterwards, it is obvious that we can work to double the limits of accuracy, without altering the original tolerances.

The estimate of 98 per cent. referred to above can be obtained by an approximate numerical calculation based on the figures given in ENGINEERING (*loc. cit.*). But an analytical derivation is given at the end of this article, based on the theoretical Gauss' law of distribution of errors. In the theory thus given, besides obtaining the figure of 98 per cent., it is shown that the average accuracy of fit when two articles of equal workmanship and tolerance are tried together, is not equal to one-half



the original average accuracy of either article (as is usually thought), but is equal to the original average accuracy, diminished in the ratio of 1 to $\sqrt{2}$. By accuracy here is meant the reciprocal of the mean probable error.

In actual practice, the workman tries to keep on the big side for the shaft or pin, in order to avoid the risk of getting outside the limits of error. This is well shown by the relative positions of diagrams A and B. Probably, similar effects will be observed in the case of the holes. Assuming this, the resultant mean clearance for the 98 per cent. is therefore about 12 $\times$ 10^{-4} in., instead of 13$\times$$10^{-4}$ in., as was intended for all the pins.

The theory we give assumes that positive and negative errors are equally likely, for like amounts. If a correction is made, as above, to the mean clearance or allowance, to allow for this not being the case, the theory may still be applied, and it is then seen that the workman has been really working to a higher degree of accuracy than is assumed below. The effect is therefore to improve the estimate of 98 per cent. already obtained.

If we assume some standard kind of fit, *e.g.*, a running fit, having a mean allowance of a, let the hole be of standard size D (tolerance $\pm$ T_1), and the shaft of standard size $D - a$ (tolerance $\pm$ T_2). In practice, T_2 is frequently the same as T_1, and in what follows this will be assumed.

In general, the actual size of the hole will be:

$$D_h = D + E_1, \text{ where } -T_1 < E_1 < T_1 \quad . \quad (1)$$

whilst the actual size of the shaft will be:

$$D_s = (D - a) + E_2, \text{ where } -T_2 < E_2 < T_2 \quad (2)$$

If we base our results on observations of a very large number of measurements, the errors E_1 and E_2 may be taken as following in their distribution the Gauss error law.* Thus the probability of the diameter D_h lying between the limits $D + E_1$ and $D + E_1 + d E_1$, will be, for a given workman and machine:

$$\frac{h_1}{\sqrt{\pi}} e^{-h_1^2 E_1^2} d E_1 \quad . \quad . \quad . \quad (3)$$

where h_1 is a constant peculiar to the workman and machine, while e is the base of Napierian logs.

Similarly, the probability that D_s lies between the values $(D - a) + E_2$ and $(D - a) + E_2 + d E_2$ is:

$$\frac{h_2}{\sqrt{\pi}} e^{-h_2^2 E_2^2} d E_2 \quad . \quad . \quad . \quad (4)$$

where h_2 is another constant, which may be different from h_1.

Since the errors E_1 and E_2 are independent, the probability, $p\, d E_1\, d E_2$, that both errors occur simultaneously, between the limits specified, is:

$$p\, d E_1\, d E_2 = \frac{h_1 h_2}{\pi} e^{-h_1^2 E_1^2 - h_2^2 E_2^2} d E_1\, d E_2 \quad (5)$$

Let $D_h - D_s = a + E$; then E may be called the combined error. Obviously:

$$E = E_1 - E_2 \quad . \quad . \quad . \quad (6)$$

E_1 and E_2 may be each either positive or negative. The combined error E is important in practice as determining the character of the fit. In the case considered, E may vary from $E_1 - (E_2 + d E_2)$ to $(E_1 + d E_1) - E_2$, which gives a total range of combined error:

$$d E = d E_1 + d E_2 \quad . \quad . \quad . \quad (7)$$

Now p can be written:

$$\frac{h_1 h_2}{\pi} e^{-h_1^2 E_1^2 - h_2^2 (E_1 - E)^2}$$

$$= \frac{h_1 h_2}{\pi} e^{-\frac{h_1^2 h_2^2}{h_1^2 + h_2^2} E^2 - (h_1^2 + h_2^2)\left(E_1 - \frac{h_2^2 E}{h_1^2 + h_2^2}\right)^2}$$

The probability of the error E having the variation lying between O and $d E$ can be obtained by noting that E can be made up of any value of E_1, between T_1 and $-T_1$ (in practice, this can be assumed as between ∞ and $-\infty$), combined with the corresponding value E_2 given by equation (6), viz., $E_2 = E_1 - E$.

We obtain the required probability by integrating p with respect to E_1, between limits ∞ and $-\infty$; and then taking into account the relation $d E_2 = d E$, which holds from (7), after elimination of E_1.

If ϕ (E) . $d E$ is the required probability of error E having the mean value E and a maximum variation $d E$, we find:

$$\phi(E)\, d E = \frac{h_1 h_2}{\pi} e^{-\frac{h_1^2 h_2^2}{h_1^2 + h_2^2} E^2} \cdot d E \cdot$$

$$= \int_{E_1 = -\infty}^{E_1 = \infty} e^{-(h_1^2 + h_2^2)\left(E_1 - \frac{h_2^2 E}{h_1^2 + h_2^2}\right)^2} d E_1$$

$$= \frac{h_1 h_2}{\pi} \cdot e^{-\frac{h_1^2 h_2^2}{h_1^2 + h_2^2} E^2} \cdot d E_2 \cdot \frac{\sqrt{\pi}}{\sqrt{h_1^2 + h_2^2}} \cdot$$

Putting now $d E_2 = d E$, we find that:

$$\phi(E) \cdot d E = \frac{h_1 h_2}{\sqrt{h_1^2 + h_2^2}} \cdot \frac{1}{\sqrt{\pi}} e^{-\frac{h_1^2 h_2^2}{h_1^2 + h_2^2} \cdot E^2} d E$$

$$= \frac{h}{\sqrt{\pi}} e^{-h^2 E^2} \cdot d E \quad . \quad . \quad . \quad (8)$$

where:

$$h = h_1 h_2 / \sqrt{h_1^2 + h_2^2} \quad . \quad . \quad . \quad (9)$$

This is the Gauss law of error, but now the value of h to be used is $h_1 h_2 / \sqrt{h_1^2 + h_2^2}$. The procedure adopted above is a modification of that found in Brunt (*loc. cit.*, Section 15). It is shown in books on the "Theory of Errors,"* that the so-called "probable error" r, of a series of measurements whose errors may be assumed to follow the Gauss law, is given by:

$$h\, r = 0.47696 = \rho, \text{ say} \quad . \quad . \quad . \quad (10)$$

Thus the accuracy of such a series can be taken as proportional to h. Putting $h_1 = h_2$ in equation (9), we see that the value of h to be taken for the combined error is $h_1/\sqrt{2}$. We thus perceive that the effect of fitting shaft and hole is not to halve the accuracy of the allowance, as might perhaps be supposed, but to diminish it in the ratio of 1 to $\sqrt{2}$.

Taking the same example as mentioned, and assuming that $h_1 = h_2$, and that T = $\pm$ 5 $\times$ 10^{-4}, for both shaft and hole; and assuming that it is found that 90 per cent. of both holes and shafts are found to fall within half these limits, it is easy then to calculate h_1, which is assumed equal to h_2.

* See Brunt, "Combination of Observations," Chapter II.

* *e.g.*, Brunt, Section 17; or Weld, "Theory of Errors," Section 58.

The probability that the error E_1 shall be between b and $-b$ is:

$$\frac{2\,h_1}{\sqrt{\pi}}\int_0^b e^{-h_1^2 E_1^2}\,d\,E_1 = \frac{2}{\sqrt{\pi}}\int_0^{h_1 b} e^{-t^2}\,dt$$

From the tables,* we find that

$$\frac{2}{\sqrt{\pi}}\int_0^{\infty} e^{-t^2}\,dt$$

has the value 0·900, or 90 per cent. when $x = 2{\cdot}44$. Thus $h_1 b = \rho\, x = 2{\cdot}44\,\rho$; and using the value of $\rho\,(= 0{\cdot}47696)$ given in (10), we find, if $b = 2{\cdot}5 \times 10^{-4}$, that $h = 2{\cdot}44\ \rho/2{\cdot}5 \times 10^{-4} = 4{\cdot}655 \times 10^3$.

The proportion of cases, according to the Gauss law, which have an error (tolerance) equal to $\pm 5 \times 10^{-4}$, is therefore:

$$\frac{2}{\sqrt{\pi}}\int_0^{2\,h_1 b} e^{-t^2}\,dt = \frac{2}{\sqrt{\pi}}\int_0^{2\,\rho\,x} e^{-t^2}\,dt$$

$$= \frac{2}{\sqrt{\pi}}\int_0^{4{\cdot}88\,\rho} e^{-t^2}\,dt = 0{\cdot}999$$

and can thus be regarded as practical certainty.

With the combined shaft and hole, both having a tolerance of $\pm 5 \times 10^{-4}$, the combined errors must in all cases fall between the limits $\pm 10 \times 10^{-4} = \pm 4\,b$. But a very considerable proportion will fall within half these limits, i.e., limits of $\pm 5 \times 10^{-4} = \pm 2\,b$. In this case, the new h has the value:

$$h = \frac{h_1}{\sqrt{2}} = \frac{2{\cdot}44\,\rho}{\sqrt{2} \times 2{\cdot}5 \times 10^{-4}} = 3{\cdot}29 \times 10^3$$

and the proportion falling within the limits of error $\pm 5 \times 10^{-4}$ is:

$$\frac{2}{\sqrt{\pi}}\int_0^{h\,b\,\sqrt{2}} e^{-t^2}\,dt = \frac{2}{\sqrt{\pi}}\int_0^{\rho\,x\sqrt{2}} e^{-t^2}\,dt$$

$$= \frac{2}{\sqrt{\pi}}\int_0^{3{\cdot}45\,\rho} e^{-t^2}\,dt = 0{\cdot}980$$

Thus only 2 per cent. of the fits would have to be revised to get an accuracy of $\pm 5 \times 10^{-4}$ in the final combined result; in spite of the fact that the tolerances allowed on each of the shafts and holes were the same, viz., $\pm 5 \times 10^{-4}$.

The question of the workman continually trying to keep on the big side with the shaft and on the small side with the hole is equivalent to diminishing the mean allowance a in the above discussion. Making due provision for this alteration in a, it is seen that the workman is really working to a higher degree of accuracy than has been indicated, i.e., h_1 and h_2 are actually larger than is assumed above.

Further experiments on the errors obtained when working to given tolerances would be useful in determining to what extent the Gauss law of errors applies to a large number of finished parts. The results here given, however, go to show that for a specified accuracy of fit of interchangeable parts, the usual tolerances employed can be considerably increased, without getting on the average more than a very small proportion of misfits. As in practice, these misfits will, in the main, be on the safe side, they can be readily readjusted by grinding, and the economic possibilities of such procedure are obvious.

* *e.g.*, Brunt, *loc. cit.*, page 19.

THE WAR DEVELOPMENT OF THE TORPEDO-BOAT DESTROYER.

NOT the least interesting feature of the war at sea has been the enormous development which has taken place in the scope and importance of the work performed by the torpedo-boat destroyers of the British Navy. To the submarine activities of the enemy this development is entirely due, and the measure of success with which the new duties were carried through was shown by the steadily declining success of the enemy submarines in their attacks on allied and neutral merchant vessels.

Some idea of the value of the work performed by this class of vessel may be gained from the fact that in addition to their ordinary scouting and other duties with the fleet the following among other new services were organised and carried through:—patrol duties, mine sweeping, mine laying, submarine hunting, involving the use of the various types of submarine sweep gear which were devised as a means of coping with enemy submarines and convoy work. Multiplications of duties naturally led to an urgent demand for large numbers of new vessels of this class, and no inconsiderable part of the enormous warship building effort of this country during the war was directed to the building of torpedo boat destroyers to meet this demand.

So great was the demand for vessels of this class that several firms with no previous experience of destroyer building were called upon to undertake the work, while the firms having previous experience were pressed to speed up construction and accelerate completion and delivery. The response of the shipyards and engine works—in spite of labour shortage, difficulty of getting material and items of equipment, and in some cases, lack of experience—has been magnificent alike in regard to quantity and quality.

During the period of active hostilities—August 4, 1914, to November 11, 1918, 25 flotilla leaders and 280 torpedo-boat destroyers were completed and delivered to the Government by 16 British shipyards. Of this total of 305 vessels, eight Clyde firms contributed no less than 156. The totals delivered from August 4, to the end of each year, were as follows: To end of 1914, 2 leaders, 29 destroyers, total 31; to end of 1915, 6 leaders, 31 destroyers, total 37; to end of 1916, 8 leaders, 88 destroyers, total 96; to end of 1917, 3 leaders, 66 destroyers, total 69; to November 11, 1918, 6 leaders, 66 destroyers, total 72; giving totals as stated of 25 leaders and 280 destroyers. Of these totals 4 leaders and 8 destroyers were under construction to the order of foreign Governments at the outbreak of war, but were subsequently taken over by, and completed for, the British Government. Typical vessels of the various classes, built by different firms, are illustrated in Plates XX to XXIII and on page 163.

The progress made in the adoption of geared turbines for all classes of torpedo-boat destroyers is shown by the following figures, which give the number of vessels fitted with geared turbines delivered from August 4, 1914, to end of each year: To end of 1914, 2 destroyers; to end of 1915, none; to end of 1916, 15 destroyers; to end of 1917, 2 leaders, 59 destroyers; to November 11, 1918, 6 leaders 62 destroyers; giving totals of 8 leaders and 148 destroyers respectively. A set of twin-screw geared turbines is illustrated on page 378.

The contribution of individual firms are extremely interesting, and it is worthy of note that notwithstanding their very substantial contributions to other branches of the naval and mercantile services, Messrs. John Brown and Co., Limited, Clydebank, and Messrs. the Fairfield Company, Limited, Govan, occupy first and third places with contributions of 33 and 28 destroyers respectively, while it is of interest to note that H.M.S. Scythe, built by Messrs. John Brown and Co., Limited, was delivered less than six months after the keel was laid. Other notable individual contributions were: Messrs. Thornycroft, Southampton, 29 vessels, including 2 leaders; Messrs. Swan Hunter, 26 vessels; Messrs. Yarrow, Scotstoun, 25 vessels; Messrs. William Denny and Brothers, 24 vessels, including 2 leaders; Messrs. J. S. White and Co., Cowes, 23 vessels, including 5 leaders; Messrs. Hawthorn Leslie, 21 vessels, including 3 leaders. When it is considered that all these vessels were fitted out in practically pre-war detail, and that fittings and mechanism have become progressively more complicated, also that the later types of destroyer have increased in size and weight, the merit of the performance of the shipbuilding and engineering firms concerned will be appreciated.

At the time of the outbreak of war the early destroyers of the "M" class were under construction in several yards throughout the country. These vessels were 265 ft. long between perpendiculars and were designed for a speed of 34 knots at about 900 tons displacement. The armament consisted of three 4-in. Q.F. guns and four 21-in. torpedo tubes arranged in pairs. Steam at 250 lb. pressure was supplied by three Yarrow boilers to the turbines. These were of the Parsons or Brown-Curtis type driving direct on to three lines of shafting with three screws and developing about 25,000 shaft horse-power at 750 revolutions.

The vessels comprising the first War Programme, ordered in September, 1914, were in all essentials repeats of the "M" class (Figs. 5 and 7, Plates XXII and XXIII). With slight alteration in minor details this design remained until the middle of 1915, when the "R" class were ordered. The essential difference between the "M" and "R" classes was in regard to machinery—the latter being fitted with geared turbines with underslung condensers driving two shafts in place of the three shafts with direct drive in the earlier classes, while a slight modification was made to the lower part of the Yarrow boilers. Three Yarrow boilers were again fitted, and the shaft horse-power was about 27,000, the revolutions being reduced to 350. Practically no alteration was made in the hull, the dimensions and armament remaining unaltered.

The next development of note was that embodied in the design of the "V" and "W" classes (Fig. 6, Plate XXII) ordered in the latter part of 1916. These vessels were considerably larger than the previous class, but were fitted with machinery of the same type and power as the "R" class. The length was increased to 300 ft. between perpendiculars and the displacement to about 1,300 tons. The armament was increased to four 4-in. Q.F. guns of a heavier type than the "R" class, and one 3-in. anti-aircraft gun, while two sets of 21-in. triple torpedo tubes were fitted.

The "S" class, which followed, showed a return to the smaller dimensions—length and displacement remaining the same as in the "R" class, but structural alterations, notably to the forecastle deck, were made. Machinery was the same as for previous class; but a rearrangement of boilers enabled one of the three funnels to be dispensed with. The armament consisted of three 4-in. Q.F. guns and one light anti-aircraft gun, two sets of 21-in. double torpedo tubes on the middle line of upper deck and two single 18-in. torpedo tubes placed one on each side of the upper deck just abaft the break of the forecastle. The "S" class is illustrated by Fig. 4, Plate XXI.

The class under construction at the conclusion of hostilities, modified "W's," shows yet another change—in that the dimensions of the "V" and "W" classes, together with their machinery and boiler arrangements, are again favoured. The armament of these vessels is increased to four 4·7 B.L. guns, a 3-in. anti-aircraft gun and two sets of 21-in. triple torpedo tubes of increased power. These vessels are the largest, the most heavily armed and the most seaworthy destroyers yet designed for the British Admiralty, and in many details of the design suggest a small light cruiser rather than the destroyer type of a few years ago.

The flotilla leaders, which are illustrated by Figs. 1, 2, and 8, Plates XX and XXIII, conform generally to the dimensions and armament of the "W's" and modified "W's," but the horse-power has been increased so as to maintain the speed with an increased displacement.

Owing to war conditions the extensive trials of pre-war days have been greatly curtailed, and such full-power trials as have taken place have been at such widely-differing draughts and displacements for vessels of the same class, and have been carried out over measured courses differing so greatly in depth of water, &c., that accurate comparisons are impossible. In general, however, it can be said that the vessels of the smaller classes showed speeds up to 39.11 knots, while the 300-ft. class showed speeds up to 35.55 knots.

Owing to its high speed, light draught and good manœuvring qualities the destroyer quickly proved itself the most suitable type of vessel for anti-submarine warfare, and several devices for dealing with these enemies were devised and fitted with the object of rendering them still more efficient for this work. Among the first devices adopted was the incorporation in the bow structure of a solid cast or forged steel ram, in association with double shell plating forward. The object was to enable the destroyer to ram a hostile submarine lying on or near the surface with the certainty of doing the maximum of damage to the submarine with the

minimum of damage to the destroyer. This device was discarded in vessels of the "S" class, but has been retained in the later designs.

Many of the earlier vessels were fitted with mine-sweep gear, while the "Burney" type of submarine sweep gear was also very extensively fitted. This latter was supplemented by depth charges discharged from shoots at the stern of the vessel and released by hand power direct or by hydraulic power from the bridge. Sweep gear of all kinds has been omitted in the later vessels, and additional numbers of depth charges are now carried. These are dropped over the stern, as already described, or are shot from the deck by means of a "Thornycroft" thrower, one of which latter is fitted on each side of the upper deck aft.

A number of vessels were specially fitted out for the purpose of laying mines, and mine rails and discharging apparatus to accommodate as many as 50 mines were provided. As this employment was of a temporary character the whole structure had to be made readily removable, and as some of the guns and torpedo tubes had to be removed to accommodate the mines and rails, these items of armament had also to be made readily portable. Anti-aircraft guns, growing in size from 1-pounder, have been fitted in successive classes, and the vessels building at present are armed with a 3-in. high-angle gun. In addition to the usual voice-pipe control, guns and torpedo tubes are now directed and fired electrically from the bridge, and in the vessels now building a rangefinder is being fitted on the upper bridge. Hydraulic gear controlling the elevation and training of searchlights is installed and fitted on the bridge, and is so arranged that any motion of a telescope sight on the gear is at once transmitted to the searchlight. This ensures that the beam of light and the sight always bear on the same point. Among improvements affecting the comfort of the officers and crew may be mentioned the lining of the ship's sides and decks of all living spaces with an insulating material, asbestocel and venesta lining, and the mechanical supply of warmed fresh air to all crews' quarters.

In the operation of the highly successful convoy system for merchantmen the destroyers played an important part, and indeed there is practically no phase of the naval operations in which they have not done conspicuous and successful work.

Owing to the secrecy necessarily imposed during the war, as to numbers and types of war vessels built, it has been impossible to give any information on the subject, but now that the ban has been removed, the following tables giving details regarding flotilla leaders and destroyers completed and delivered during the period August 4, 1914, to November 11, 1918, will be of interest :—

Total of Vessels Delivered.

—	End of 1914.	End of 1915.	End of 1916.	End of 1917.	Nov. 11, 1918.	Total.
Leaders	2	6	8	3	6	25
Destroyers.. ..	29	31	88	66	66	280
Totals for Year..	31	37	96	69	72	305

FIG. 9. VIEW ON DECK OF THE FLOTILLA LEADER "SHAKESPEARE"; MESSRS. JOHN I. THORNYCROFT AND CO., LIMITED, SOUTHAMPTON.

Of the above, 3 leaders and 27 destroyers have been lost by enemy action.

Details of vessels completed by individual firms are as follow, flotilla leaders being indicated thus (*) :—

John Brown and Co., Limited, Clydebank :—Milne Morris, Moorsom, Medea, Medusa, Mons, Marne, Mameluke, Ossory, Napier, Narborough, Penn, Peregrine, Romola, Rowena, Restless, Rigorous, Simoom, Skate, Tarpon, Telemachus, Vance, Vanquisher, Wakeful, Watchman, Simoom, Scimitar, Scotsman, Scout, Scythe, Seabear, Seafire, Searcher—Total, 33.

Messrs. J. I. Thornycroft and Co., Southampton :—Shakespeare,* Spenser,* Unity, Victor, Lance, Lookout, Meteor, Mastiff, Michael, Milbrook, Minion, Munster, Nepean, Nereus, Patrician, Patriot, Rapid, Ready, Rosalind, Radiant, Retriever, Taurus, Teazer, Viceroy, Viscount, Wolsey, Woolston, Speedy, Tobago—Total, 29.

The Fairfield Shipbuilding and Engineering Company, Govan :—Lawford, Louis, Lydiard, Laforey, Melampus, Melpomene, Mandate, Manners, Mindful, Mischief Onslaught, Onslow, Observer, Offa, Orcadia, Oriana, Pheasant, Phœbe, Tempest, Undine, Vendetta, Venetia, Walrus, Wolfhound, Sikh, Sirdar, Somme, Spear—Total, 28.

Messrs. Swan, Hunter and Wigham Richardson, Wallsend and Walker :—Matchless, Marmion, Martial, Nessus, Mary Rose, Menace, Nestor, Partridge, Pasley, Radstock, Raider, Sorceress, Vimiera, Torrent, Torrid, Tower, Violent, Vittoria, Tilbury, Tintagel, Whirlwind, Wrestler, Shark, Sparrowhawk, Splendid, Sportive—Total, 26.

Messrs. Yarrow and Co., Limited, Scotstoun :—Landrail, Laverock, Miranda, Minos, Manly, Moon, Morning Star, Mounsey, Musketeer, Nerissa, Relentless, Rival, Sabrina, Strongbow, Surprise, Sybille, Truculent, Tyrant, Ullswater, Vivacious, Vivien, Torch, Tomahawk, Triphon, Tumult—Total, 25.

Messrs. William Denny and Brothers, Limited, Dumbarton :—Nimrod,* Anzac,* Loyal, Legion, Ardent, Maenad, Marvel, Mystic, Narwhal, Nicator, Petard, Peyton, Rocket, Rob Roy, Redgauntlet, Valkyrie, Valorous, Vehement, Venturous, Walker, Westcott, Senator, Sepoy, Seraph—Total, 24.

Messrs. J. S. White and Co., Limited, Cowes :—Faulknor,* Broke,* Lightfoot,* Botha,* Tipperary,* Laurel, Liberty, Magic, Moresby, Medina, Medway, Sable, Setter, Trenchant, Tristram, Vampire, Vectis, Vortigern, Winchelsea, Winchester, Tribune, Trinidad, Trojan—Total, 23.

Messrs. Hawthorn, Leslie and Co., Limited, Newcastle :—Marksman, Montrose, Stuart, Mentor, Mansfield, Talisman, Termagent, Trident, Turbulent, Pigeon, Plover, Sarpedon, Starfish, Stork, Thisbe, Verdun, Verulam, Thruster, Warwick, Wessex, Versatile—Total, 21.

Messrs. William Doxford and Sons, Limited, Sunderland :—Opal, Ophelia, Opportune, Oracle, Orestes, Orford, Orpheus, Octavia, Norseman, Oberon, Redoubt, Recruit, Ulysses, Umpire, Vega, Velox, Walpole, Whitley—Total, 18.

Messrs. Palmers' Shipbuilding Company, Hebburn and Jarrow :—Leonidas, Lucifer, Murray, Myngs, Nonsuch, Negro, Norman, Northesk, Oriole, Osiris, North Star, Nugent, Urchin, Ursa, Waterhen, Wryneck—Total, 16.

Messrs. Cammell Laird and Co., Limited, Birkenhead :—Kempenfelt,* Abdiel,* Gabriel,* Ithuriel,* Parker,* Grenville,* Hoste,* Seymour,* Saumarez,* Scott,* Bruce,* Douglas,* Campbell,* Valentine, Valhalla—Total, 15.

Messrs. William Beardmore and Co., Limited, Dalmuir :—Llewellyn, Lennox, Lassoo, Lochinvar, Pelican, Pellew, Satyr, Sharpshooter, Tancred, Ulster, Vancouver, Vanessa, Vanity, Tactician, Tara—Total, 15.

Messrs. Stephen and Co., Limited, Linthouse :—Noble, Nizam, Nomad, Nonpariel, Prince, Pylades, Sturgeon, Sceptre, Tormentor, Tornado, Vesper, Vidette, Vovager, Sabre—Total, 14.

Messrs. Scotts' Shipbuilding and Engineering Company, Limited, Greenock :—Obedient, Obdurate, Paladin, Partheon, Plucky, Portia, Tirade, Ursula, Westminster, Windsor, Swallow—Total, 11.

Messrs. Harland and Wolff, Limited, Govan :—Salmon, Sylph, Skilful, Springbok, Tetrarch, Tenacious—Total, 6.

Messrs. The London and Glasgow Shipbuilding and Engineering Company, Limited, Govan :—Owl.

Of the above firms, Messrs. John Brown and Co., Thornycroft, Fairfield, Yarrow, White, Cammell Laird, Beardmore, Scott, Harland and Wolff, and London and Glasgow Company, completed the hulls and machinery for all their vessels; while Messrs. Denny completed all except one of their vessels, which latter was engined by the Parsons Company. Additional machinery was supplied to other builders by the above firms as follows: Messrs. John Brown and Co., 2 vessels; Messrs. Beardmore and Fairfield, 1 vessel each. Machinery for vessels built by Messrs. Swan, Hunter, Doxford, Hawthorn Leslie, Palmer and Stephen, was supplied by the following firms: Wallsend Slipway Company, 24 vessels; Parsons Marine Turbine Company, 16 vessels; C. A. Parsons and Co., 3 vessels; Richardsons, Westgarth and Co., 8 vessels; J. Brown and Co., Clydebank, 2 vessels; Messrs. Babcock and Wilcox, 4 sets of boilers; Messrs. Willans and Robinson, G. Clark, Limited, Sunderland, Palmers Shipbuilding Company, Messrs. Beardmore, Dalmuir, Fairfield, Govan, 1 vessel each.

Finally, detailed reference may be made to the engravings on Plates XX to XXIII, and on the present page and page 378, Figs. 1 and 2, Plate XX, illustrate the flotilla leaders Scott and Kempenfelt, which were constructed by Messrs. Cammell, Laird and Co., Limited, of Birkenhead, who, as shown on the list already given, built 13 vessels of this type. The Kempenfelt ran her trials in Liverpool Bay, and maintained a speed of 35·1 knots. There was no opportunity for any of the other vessels of the class making special trials.

On Plate XXI there is illustrated the Brook. This vessel, which was one of the earliest of the flotilla leaders delivered during the war, was built by Messrs. J. S. White and Co., Limited, of East Cowes, and her brilliant action in the Straits of Dover constituted one of the most heroic and successful episodes in the history of the war. On the same plate we publish the photograph of the Sabre, belonging to the "S" class. This vessel was built by Messrs. Alexander Stephen and Son, Linthouse, Glasgow, who, although they had had no previous

practical experience of warship building, did most satisfactory service during the war in the construction of 14 torpedo-boat destroyers.

On Plate XXII there are illustrated two of the typical vessels of the large fleet of 33 built by Messrs. John Brown and Co., Limited, of Clydebank. Fig. 5 shows the "M" class and Fig. 6 the "V" class, to both of which classes detailed reference has already been made. On Plate XXIII there are illustrated the Miranda, built by Messrs. Yarrow and Co., Limited, of Scotstoun, and the flotilla leader Shakespeare, built by Messrs. J. I. Thornycroft and Co., Limited, of Southampton. As is well known, these two firms have contributed largely to the development of design of this type of warship, from the very inception of the class, and their work during the war, alike in design and construction, has been signally successful. On page 363 there is given a deck view of Messrs. Thornycroft's destroyer, while on page 378 are two perspective views of the turbines in the erecting shop. The Shakespeare was, like the Spencer and Wallace, the largest unit built by Messrs. Thornycroft for the Admiralty, and the geared turbines were designed to meet the guaranteed speed of 35 knots. The particulars of the vessels are as follows: Length on water-level, 325 ft. 9 in.; beam, 31 ft. 9 in.; depth, 19 ft. 9 in.; armament, five 4·7 guns, one 3-in. H.A. gun, six 21-in. torpedo tubes and two depth-charge throwers. The oil fuel capacity is 500 tons, and the complement 157 men. The displacement with all oil on board is just under 2,000 tons. The speed of the Shakespeare on official trial, which was run in the Channel, was tested by four runs over a 20 fathoms course, the ship being in fully-equipped condition with all armament and ammunition, but with 3 hours' oil fuel only on board, representing her condition in the middle of a 6 hours' full-power trial. The speed obtained in this depth of water was 38·95 knots. The Spenser was tried at a deeper draught, with 223 tons of oil on board. Her speed was 37·56 knots over the same course. An order for a third vessel, the Wallace, followed. When the Wallace was completed, the war being over, the firm asked permission for the vessel to be allowed to make a series of trials at Skelmorlie to ascertain the difference in performance in deep water as compared with that in 20 fathoms. This was agreed to. The vessel was first run over the 20-fathom course in the Channel, under the same loading conditions as the Shakespeare. Her speed on official trial there was 37·79 knots, a knot below that of the Shakespeare. On trial at Skelmorlie the following week at the same displacement the mean speed of six runs was 37·72 knots, but this was obtained at an increase of 900 h.p. The machinery of the flotilla leaders (see page 378) is of the two-shaft Brown–Curtis geared type, and was designed from basis plans supplied by Messrs. John Brown of Clydebank for 44,000 shaft horse-power. This has been exceeded on trial, the power of the Wallace at Skelmorlie being 45,500. There are four boilers of the usual modern type with circular lower barrels.

THE MEASUREMENT OF FLUID VELOCITY AND PRESSURE.

By J. R. PANNELL, A.M.I.M.E., F.R.Aë.S.

(*Continued from page* 334.)

THE DIRECTION AND VELOCITY METER.

The original form of this instrument was described by Sir Horace Darwin, F.R.S., in his Wilbur Wright lecture to the Aeronautical Society of Great Britain.* The yaw meter, as it is called, depends for its sensitivity on the rate of change of pressure in an open ended tube as its inclination to the direction of flow is varied and it may be seen from Fig. 18 that the curve of pressure in such a tube plotted on an angle of inclination base, is extremely steep between the angles 45 deg. and 95 deg.

The apparatus is shown diagrammatically in Fig. 19, in which the two open ended tubes are set in the form of a Y, the pressure in each tube being transmitted to a diaphragm, D. The motion of these diaphragms is transmitted by the rods R to the lever L, through hinge joints. The lever L can turn freely about the point O and when the forces on the two rods R are not equal the lever will take up a position parallel to the line of action of the resultant of the two forces. A pointer P is attached to the lever, and the scale may be calibrated to read directly the angle between the axis of the head and the wind direction. The indications of the instrument are independent of speed since for a given angle of the wind the *ratio* of the forces on the diaphragms is constant.

This instrument does not, however, appear to have been very extensively used the more common plan being to turn the yaw-head until the pressures

Fig. 18. EFFECT OF INCLINING A PITOT TUBE.
R_0-Value of $\frac{1}{2}\rho V^2$ when Axis of Pitot is along the Wind.
R_θ-Value of $\frac{1}{2}\rho V^2$ when Axis of Pitot is Inclined at Angle θ to the Wind.

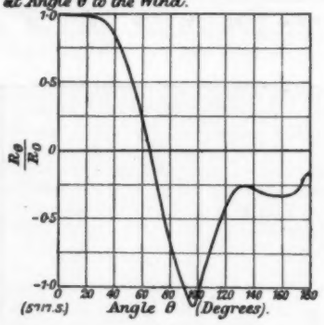
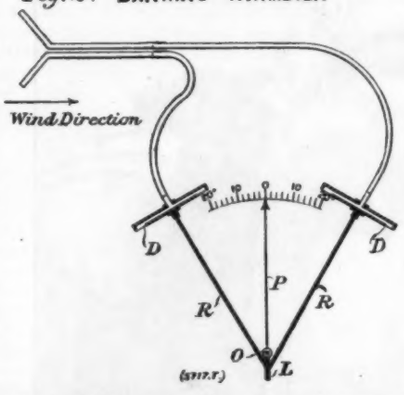


Fig. 19. DARWIN'S YAWMETER



in the two tubes are equal, and to note the angle turned through. The latter plan is probably the more accurate of the two. The "Y" form of head was used for measurement of direction on aeroplanes at the Royal Aircraft Factory, a cone suction tube similar to that of the Clift-head being fitted in order that the pressure difference between it and one of the pitot tubes could be used to indicate speed.

The angle embraced by the "Y" was originally about 90 deg., but greater sensivity is obtained if this angle is increased to 120 deg.

The yaw-head which was made at the National Physical Laboratory was a modification of Sir Horace Darwin's instrument and is shown in Fig. 20. In order that the head might be used for mapping the flow round models in the wind channel, it was essential that the instrument should be as small as possible and that the ends of the pitot tubes should be close together. For this reason the tubes are made of hypodermic syringe tubing about 0·03-in. in diameter, and are bent inwards so that the distance between the centres at the end of the tubes is only about 0·13-in. In addition to the pair of tubes A and B in the horizontal plane, there is also a similar pair C and D in the vertical plane, and a fifth tube E which is fixed inside a hollow cone. The five tubes are subsequently bent through a right angle and led to a circular rod 0·25-in. in diameter, where they connect to five passages which are cut in the rod. This rod is continued downwards to a point 6¼ in. below the open ends of the tubes, where it is attached to a spindle in such a manner that when this spindle is held in the chuck of the balance the ends of the tubes are in the vertical axis of rotation. This precaution is necessary in order that the coordinates of the head may not be changed when the instrument is rotated about a vertical axis. The tubes are connected by small bore rubber tubing to two three-way and one two-way glass cocks outside the channel, an arrangement which enables the various pairs of tubes to be connected in turn to the manometer without removing the rubber tubing, or stopping the wind.

Before observations are taken it is necessary to calibrate the head and for this purpose it is mounted in the unobstructed channel with its axis *horizontal* in such a manner that the rotation of the balance about its vertical axis is equivalent to the inclination of the wind in a *vertical* plane, when the instrument is mounted with its axis vertical. The head is adjusted until the pressures in tubes A and B (now in a vertical plane) are equal, after which readings are taken of the pressure difference between tubes C and D (which are in a horizontal plane) and in A and E for various angles of the instrument. These observations must be repeated at different speeds over the range which will be required in the subsequent experiments. Measurement of the pressure difference between tubes A and E is necessitated by the fact that the reading is slightly affected by the angle of the relative wind in the C and D (*i.e.*, the normally vertical) plane.

The next step is to mount the yaw-head in its normal position with its axis vertical and determine the position of the balance at which the pressures in tubes A and B (now in a horizontal plane) are

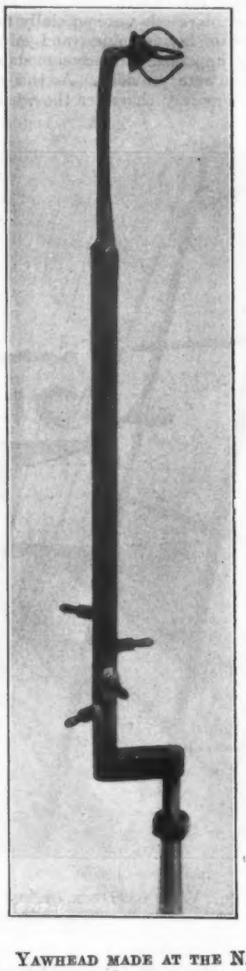


FIG. 20. YAWHEAD MADE AT THE NATIONAL PHYSICAL LABORATORY.

* *Aeronautical Journal*, July, 1913.

equal. The reading on the angle scale of the balance forms a zero relative to which subsequent angle readings are to be reckoned. The glass cocks are now turned so that the tubes C and D are connected to the manometer and the pressure difference observed; if the axis of the instrument was accurately vertical and the tubes C and D symmetrical there would be no pressure difference, but in practice there is a small difference which must be corrected for in reducing the results. The instrument is now ready for the measurement of any disturbance of the wind caused by placing a model in the channel.

A chart may be drawn in the manner shown in Fig. 21 from which the magnitude of the resultant velocity and its inclination to the horizontal can be read when observations of the pressure differences between tubes C and D and tubes A and E have been taken. The angle in the horizontal plane has been read off directly from the balance, and the resultant wind is now determined in both direction and magnitude.

Owing to the considerable length of fine bore tubing in the instrument the pressure gauge is very heavily damped, and until experience has been gained observations can only be made slowly; the use of the N.P.L. tilting manometer in connection with this head is considered in the description of that gauge which follows. The damping could be reduced to some extent by substituting a stream line support for the 0·25-in. rod referred to above; the greater cross-sectional area would then allow the passages to be larger.

Ships Logs.

The standard method by means of which the speed of naval vessels is determined is to observe the time taken to pass over a measured distance, runs being made in opposite directions to eliminate errors due to currents along the course, though cross currents will still cause a distance greater than the measured one to be traversed. These experiments are carried out at various speeds, observations being also made of the rotational speed of the propeller, a quantity which is used to indicate the ship's speed when on actual service. It should be noted that this method may lead to appreciable error if the resistance of the ship changes, an event which may easily occur due to, for instance, fouling of the bottom. An alternative plan to determining translational speed from the speed of revolution of the propeller is to use a special instrument, known as a "log" for the purpose.

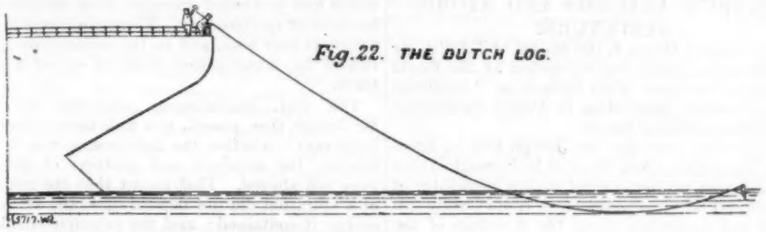


Fig. 22. THE DUTCH LOG.

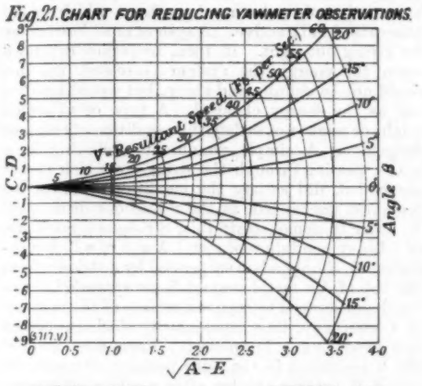


Fig. 21. CHART FOR REDUCING YAWMETER OBSERVATIONS.

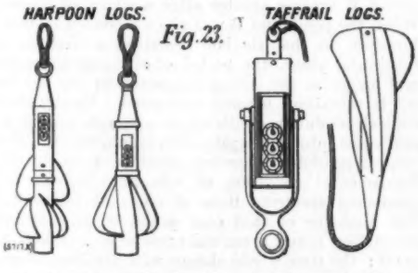


Fig. 23.

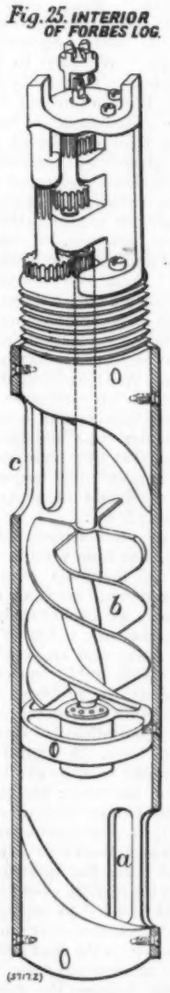


Fig. 25. INTERIOR OF FORBES LOG.

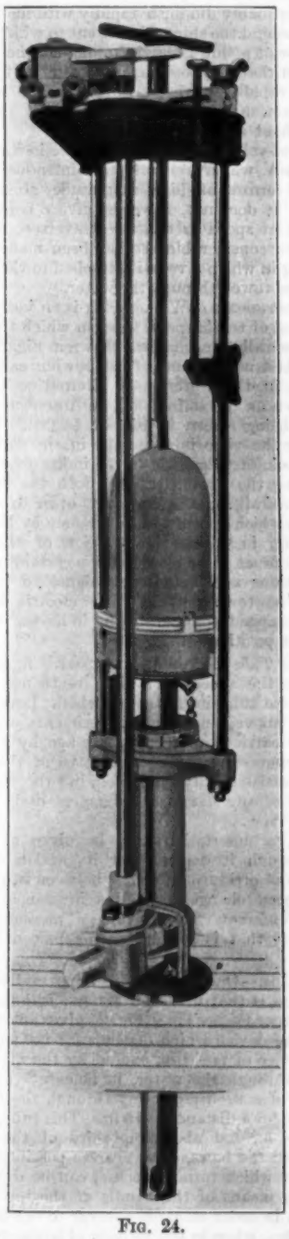


Fig. 24.

Figs. 24 and 25. The Forbes Log.

The name arose from the very old plan of throwing overboard a piece of wood attached to a cord in which knots were tied at stated distances. When it was desired to determine the ship's speed this cord was allowed to run out freely, the speed being calculated from the number of knots which ran out in unit time. The term "knot" as the naval unit of speed arose in this way, but it is interesting to note that though in using this form of log the observations of speed were of the nature "number of knots per unit time" the term knot is now used as the unit of *speed* and knots per unit time is an *acceleration*. Particular emphasis is laid upon this term as it is common to find speed erroneously given in knots *per hour*.

The Dutch Log.—The device just described is known as the Dutch log, and is still in use; the method employed in using it is shown diagrammatically in Fig. 22. The knotted line is wound on a drum which can turn freely on a shaft and to one end is attached, by means of three cords, a triangular shaped piece of wood. The cords are fastened near the corners of the triangle, one being fixed to a plug which is intended to pull out under any abnormal force and allow the piece of wood to move edgewise through the water, thus avoiding breakage of the line. The triangle of wood is thrown into the water and the cord held fast until the speed measurement is required; one man holds the drum by means of the shaft which passes through it, while another stands ready to count the knots by placing his hand lightly on the cord as it runs out. The observation is finally made by releasing the cord and noting the number of knots which pass in a given time.

It appears that the speed determined in this manner may be in error from two causes, first the motion of the wooden triangle through the water, and second the motion of the water in the wake of the ship caused either by the propellers or by the water which moves along behind the ship. The first error, which renders the observed speed too low, is believed to be small owing to the high resistance of the wooden triangle (which rides vertically in the water) and the part of the cord which is immersed. The second is of opposite sign and will probably diminish rapidly with increase of distance behind the ship; the extent to which water in the rear of a ship is carried along can be judged by the fact that it is possible for a swimmer to bathe behind a rapidly moving sailing ship and without any connection with it whatever board the ship again without assistance.

The chief value of the Dutch log lies in its simple construction which renders the introduction of accidental errors of high magnitude almost impossible. It does not, however, give a continuous indication of speed or distance traversed, and for that reason considerable use has been made of the type of log in which a vane is attached to the end of a cable and towed through the water.

Vane instruments.—Walker's log is an instrument of this kind of the harpoon type, in which the vane and the recording mechanism shown in Fig. 23 (left) are attached at the end of the towing cable and immersed in the water. An alternative type is that known as the taffrail log, an American design by Bliss being shown in Fig. 23 (right). In this type only the vane is immersed in the water, its rotation being transmitted to the indicator on deck by twisting the towing cable. Both the harpoon and the taffrail log are, however, open to certain objections which appear to be overcome by Kelways electric log, in which the rotation of the vane causes a contact to be closed after a certain number of revolutions and an electric signal to be sent through the towing cable. The electric current can be arranged to operate an indicator in any convenient position on the ship.

Pressure Tube Logs.—An alternative method of measuring the speed of a ship is to use one of the pressure tube instruments which have been described above, and some experiments on these lines were carried out a few years ago by Froude. It was demonstrated that apparatus of this kind could be satisfactorily employed, but the writer is not aware of any standard instrument designed for general service.

Finally, a description may be given of a log which, though it depends for its action on the variations of pressure difference between two points as the speed changes, operates in a manner so entirely different from ordinary pressure tube instruments that it can hardly be placed in this class.

Forbes Log.—One of the more important modern instruments is that made by Messrs. Elliott Bros., and known as Forbes log. Fig. 24 gives an external view of the device which depends for its action on the difference of pressure, caused by the motion of the ship through the water, in holes at the front and back of a tube projecting through the bottom of the ship for a distance of 15 in. This tube, which should be located about one-third of the ship's length from the bows, or as near as possible to the axis about which turning occurs, can be drawn up at will by means of the handle at the top of the apparatus in order to avoid damage to the tube by hawsers, &c., when in the vicinity of harbours.

The manner in which the instrument is operated can be readily seen by a reference to Fig. 25, which is a sectional view of the lower portion of the log tube. The water enters the openings, *a*, in the forward side of the tube, passes up the tube, turns the propeller *b* and leaves the tube by the openings *c* at the after side. The motion of the propeller is transmitted through the gear wheels to a commutator which sends an electric signal each 1/100th of a mile to the distance recorder whose two hands make one complete revolution in 1 mile and 100 miles respectively; there is also a continuous indication of the total number of miles travelled.

The rotation of the propeller *b* also operates a magneto-generator, the voltage at which current is generated being proportional to the speed of rotation. The current is led to voltmeters which are calibrated in knots from 5 to 30. The instrument is calibrated by running the ship over a measured course and changes of gear wheels are provided by means of which variations of 2½ per cent. can be made in the indicator readings.

(To be continued.)

SPECTRUM ANALYSIS AND ATOMIC STRUCTURE.

ON Saturday, March 8, the Master of Trinity, Sir J. J. Thomson, O.M., P.R.S., opened at the Royal Institution the course of six lectures on "Spectrum Analysis and its Application to Atomic Structure," to be delivered before Easter.

Nearly fifty years ago, Sir Joseph said in introducing his subject, Clerk Maxwell had remarked that the intelligent student, armed with a knowledge of calculus and with a spectroscope, could hardly fail to find out something about the structure of the molecule. In that expression Maxwell had been unduly optimistic. Many intelligent students possessing both these qualifications had applied themselves to the study. Spectroscopy had had its great triumphs. We owed to it the discovery of some ten elements; technically the spectroscope had wonderfully been improved; we measured by the aid of these instruments the velocities of stars and determined their constituent elements; and Hale had even given us a meteorology of the sun with magnetic cyclones and other storms. But it was only in comparatively recent years that spectroscopy had taught us anything definite as to the structure of the molecule. A simple acoustical analogue would indicate the reason. Suppose a kind of "Jazz" band, every player of which was bent upon producing as much noise with his instrument as possible, were performing in a building, impervious to light, but permeable to sound, and standing outside we tried to ascertain the nature of the instruments. What could we do? At first we should merely hear a confused noise. Watching the pitch of the notes coming out, however, we might single out particular notes and mark these down; we should notice that they were mostly associated with a series of notes of other frequencies; if, then, these frequencies should be proportional to the natural numbers 1, 2, 3 . . ., we should conclude that the notes in question must come either from string instruments or from wind instruments which produce notes of harmonic relationship. Other sounds, we should find, were not connected by a harmonic relation; we would ascribe those to drum and hammer instruments, and in this way we might disentangle the noise, and arrive at some estimate of the numbers of different instruments.

That was exactly the problem, Sir Joseph continued, which faced us in spectrum analysis. Many spectra were extraordinarily complex, showing ten-thousands of lines. A frontal attack to disentangle them would be of no avail; one could not see the forest for the trees; the problem was too hopelessly confused to be studied *en bloc*. We must try to pick out lines associated by simple relations. In the days of Clerk Maxwell's dictum much effort had been spent upon the spectrum lines on the assumption that the relation would be that of simple harmonics; that had led to negative results; the lines seemed to be distributed at random. The first successful step—always the most difficult, Sir Joseph interposed—was made by Balmer, who discovered a simple relation between the frequencies of the lines in the hydrogen spectrum. Rydberg, Kayser and Runge, and others, greatly extended this work subsequently, and an enormous amount of work was done on these theories; he would refer to the results in another lecture. In the first instance, he wished to speak of some fundamental principles of the vibrations of light, and in that connection he would like to say that the present age hardly paid enough tribute to early investigations. Spectroscopy had not originated with Bunsen and Kirchhoff about 1860, as was sometimes believed. A great deal had been done before that. The knowledge of the fact that certain substances imparted characteristic colours to flames was no doubt very old. Sir Joseph exhibited a table of Wheatstone's of 1835, illustrating observations of the flame spectra of sodium, mercury, zinc, cadmium, barium, &c.; the table showed light emissions from different parts of the spectrum. A photograph of the sun, taken by Draper in 1842, showed the solar spectrum crowded with (rather diffuse) Fraunhofer lines. The lecturer did not wish to go into details. But he quoted a historically interesting passage from Kayser's "Spectrum Analysis," that it was only the universal presence of traces of sodium salts which had prevented Herschel from becoming the inventor of spectroscopy. Everything was tried in flames at that time, and as the sodium line always turned up, investigators were led off on a wrong track.

The first, fundamental principle, to which Sir Joseph then passed, was well known, but most important: whether the light source was faint or intense, the sequence and position of the lines were not altered. That meant that the frequency of a vibration did not depend upon the amount of energy it contained; and the principle enabled us at once to rule out some hypotheses which would otherwise be attractive. A system must lose energy by giving out light. If, then, frequency depended upon the energy the system possessed, the line could not be definite and sharp, but would broaden out as the energy changed. A type of vibration might or might not satisfy this condition of constant frequency. A simple pendulum oscillating in a plane, passing through the string by which it was suspended, did satisfy the condition; the period remained unchanged, as the vibrations died away. In order to demonstrate this, Sir Joseph made use of a heavy pendulum of metal A and of a light pendulum B, simply a bob suspended by a string; from the bob of A a metal contact finger extended downward and scraped the convex surface of the mercury in a small cup, thus momentarily closing a circuit and producing a lamp flash. Each flash showed the B pendulum in the same position although the arc of B became shorter after a while, of course. When the pendulum B was given a conical motion, however, so that its bob described a circle in a horizontal plane, the period of swing grew longer and longer as the energy (imparted to the bob to set it vibrating) became exhausted. Finally that conical pendulum oscillated as a simple pendulum and came into tune again with pendulum A. The conical pendulum therefore would not satisfy the fundamental condition of vibrations capable of producing spectrum lines of constant frequency. The analogue of that case would be an electron circulating round a central nucleus in a planetary orbit; the time would change with the diminution of the energy, and in such a planetary system the frequency would vary with the energy of the system. There was one system of this kind, however, which would fulfil the condition: when an electron described an orbit round a line of magnetic force. The period of that vibration depended merely upon the magnetic force, and in that instance, therefore, the frequency would remain constant and a sharp definite line, devoid of broadening, would be produced. Sir Joseph merely mentioned this point at that stage of his lectures, remarking that it would claim attention later. For the spectrum lines associated with definite series were due to the presence in the atoms of strong magnetic forces, and it was the rotation of the electrons round those lines of magnetic force which gave rise to the lines.

Leaving the bright-line spectrum, Sir Joseph next referred to the absorption spectrum. It was produced when the light of the source passed through layers of the substance under examination; the absorption bands might be as sharp as the bright lines. In considering absorption we had to deal with a phenomenon known as resonance, the effect of an influence which acted on a body keeping time with the vibrating system. A pendulum experiment was again used for illustration. There was the heavy pendulum A, mentioned above, and a simple pendulum C, a bob of iron suspended by a string, of the same length; underneath C was an electromagnet in the shape of a vertical bar, pendulum A making and breaking the electric circuit. When pendulum C was started, it was seen to get up speed, while keeping in period with A, and it acquired

considerable energy. When pendulum C was shortened, so as not to be any longer in phase with A, its oscillation soon died out in the usual way. A tuning fork held in front of a resonator-box afforded another illustration; the capacity of the resonator had to be such that the air in it was capable of vibrating at the same period as the fork, and then the sound of the fork was reinforced. The energy which might be absorbed in resonance was very large. Supposing a sound wave were advancing towards a small vibrator. When the vibrator was not in tune with the wave, the amount of energy absorbed by the vibrator depended upon the size of the latter; a big thing would absorb more energy than a small thing. But when the two were in tune, the vibrator absorbed an amount of energy, not merely equivalent to its own cross-section, but equivalent to the area of a circle described with the wave-length as radius, 2 ft., for instance. That was a considerable area, and in this case of tuned vibrations it mattered little whether the thing was small or big; with large wave-length the energy would become very large. Certain cases of these problems had been worked out by Horace Lamb and by Rayleigh.

Such an absorption also implied an abstraction of energy of which not much might be left in consequence. Sir Joseph placed a tuning fork in front of one box resonator; the sound was reinforced; then he approached another resonator of the same shape and size, so that the fork was between the two resonator-mouths; there was little further sound reinforcement, certainly not a doubled effect, because the one resonator already absorbed much energy. From that consideration one could understand that a series of small resonators suitably grouped could act as an almost opaque screen reflecting a sound wave; each of the small resonators would cover an area of 2 ft. radius, *e.g.* That was a very important point. We had to guard ourselves against one mistake, however, Sir Joseph continued, in explaining absorption by resonance. When the intensity of a tuning fork was reinforced by a resonator, we had very good resonance, but no real absorption in the sense of a transformation of energy. When a sodium flame was surrounded by sodium vapour, all the sodium atoms in the vapour were resonators for the light given out by the flame. But if the vapour re-emitted this light, it would not be real absorption; it merely meant that sodium light was given out in other directions, and that a different distribution of the light took place. There must be something else in addition to resonance to produce absorption. When a pendulum was swinging in resonance and acquiring energy, the pull might become so strong that the string gave way. Supposing the string did break; then the pendulum bob would have the energy of a moving body, and there would be transformation of energy. Similarly in the absorption of light; there must be something torn off to cause a transformation of energy. Absorption of light did not merely mean a scattering of light; it involved a destruction of light.

Professor Thomson proceeded to show an experiment suggesting the close connection between emission of luminosity and electrical excitation. He heated two strips of platinum foil, about 1 cm. wide, 3 cm. long, in the gas flame of a large Méker burner; the strips faced one another in the flame (see diagram), and formed the terminals of a battery

(5788)

of small accumulator cells; a galvanometer was in circuit. A very small current was seen to pass through the flame. When a platinum wire dipped into sodium chloride was introduced into the flame, a powerful current was produced, so strong in fact that the galvanometer spot was thrown off the scale and would not quiet down again for some time. Thus the introduction of salt vapour into the flame produced an intense electrical effect. But it was essential that the sodium was introduced near the kathode, just below or next it, as indicated in the diagram. When the platinum wire was held near the anode, there was hardly any effect; this was shown first, and as the wire moved over to the kathode afterwards the effect increased. The same experiment could be made with iodine and other substances, always introduced near the kathode, and this electrical effect was a very frequent accompaniment of luminosity. Broadly, one might indeed say—though he would have to qualify that statement in due course—that electrification must accompany the excitation of luminosity.

What did these experiments suggest? Sir Joseph asked. In the case of the sodium flame they suggested that at one stage during the emission of light the sodium atom was positively electrified. That interpretation was generally accepted. The burning question was, however, whether the sodium atom was positively electrified while actually giving out light, or whether it had lost its electrification before the light came. For his own part, Sir Joseph was convinced that the light was emitted when the sodium atom was being neutralised again by the return of the electron whose expulsion was responsible for the positive electrification. The sodium atom, now, was credited with several electrons, and the temporary loss of one of them would still leave the atom surrounded by other electrons. In the case of hydrogen the problem was much more exciting. When the hydrogen atom had become positively electrified by losing its single atom, there was only the neutral atom left, and the question thus became fundamental: Was it the positively electrified atom which gave out the vibrations, or was it the neutral atom? The discussion of this question would, Sir Joseph remarked in conclusion, be resumed in the second lecture.

TEMPLETS, JIGS AND FIXTURES.
No. XII.

By JOSEPH HORNER.

FURTHER illustrations of milling fixtures will occupy our attention in this article. The value of these aids in milling operations appears to rank only second to their utilities in drilling and boring. The examples here given show fittings adapted to the pillar and knee, and to the Lincoln miller designs, and are therefore unlike any previously shown. They are supplied by the Kempsmith Manufacturing Company, of Milwaukee, Wis, U.S.A., for whom the Selson Engineering Company, of London, are the English representatives.

Figs. 625 to 628, page 368, show a fixture designed for roughing out, or "gashing," the teeth of bevel gears on one of the Kempsmith pillar-and-knee plain machines. The practice of dividing roughing and finishing between two distinct operations on different machines is one that is adopted extensively, since the work thrown on the finishing cutters is lessened, and restricted to their proper function, and time is economised when quantities are concerned. The work of finishing can be transferred to a machine more suitable to that purpose—to any one of the regular bevel-gear cutters using either form tools or generating methods. The fixture carries two blanks. Two gashing cutters are carried on an arbor supported between the machine spindle and driven by it, and the brace or harness which ties the arm to the knee. Though single cutters are shown, double cutters are also used if desired, to take out two adjacent tooth spaces.

The base of the fixture is fitted with tongues to the tee-grooves of the machine table, to which it is bolted down through the open slot holes seen in plan, Fig. 626. A comparison of the views shows that the blanks are mounted each on a work spindle A that fits in a boss B, cast with the base and disposed at an angle that brings the bevel of the roots of the teeth horizontally, Fig. 627. The upper portion of the boss is bushed, C, a necessary provision required in order to permit of the insertion of the bronze worm gear through which the indexing is transmitted. This gear, that surrounds each work spindle and turns it, is actuated by its steel worm of ¼ p., single-threaded, right-hand, both worms being keyed on one shaft that passes through the fixture, and each retained endwise with a bush set with a grub screw, Fig. 625. The worm shaft is actuated from one end with a lever D provided with a spring index pin, Fig, 625. The index plate has one hole to receive the peg, so that when using a single cutter, one turn of the crank is made. If a double cutter is employed, two turns are given to the crank. The blank, outlined in Fig. 627, is secured to the work spindle with a nut having a slip washer. The spindle and the bushings can be changed to suit gears of different bores.

The work spindle, Fig. 627, is seen to be provided with an annular groove of a truncated vee-section. This is used to lock the spindles firmly during cutting. A detail of the clamping mechanism is shown in Fig. 628, and portions of it in other views. It will be noticed that Fig. 628 combines two views of this detail taken at right angles. A lever E is used to turn a screw which presses on the end of a clamp-pin, and this being bevelled on the end thrusts clamp pins F, F, to right and left to lock in the annular grooves in the spindles.

The next group of illustrations, Figs. 629 to 642, are those of a fixture made by the Kempsmith Company, to be used on one of their plain millers of the Lincoln type, for dealing with the ends of connecting rods. The net output is large, being that of finishing both ends of 400 rods per day. Four rods are held in the fixture, and one set of ends is tooled at one time. The general views of the loaded fixture are given in Figs. 629 to 631, details of which are shown in subsequent illustrations.

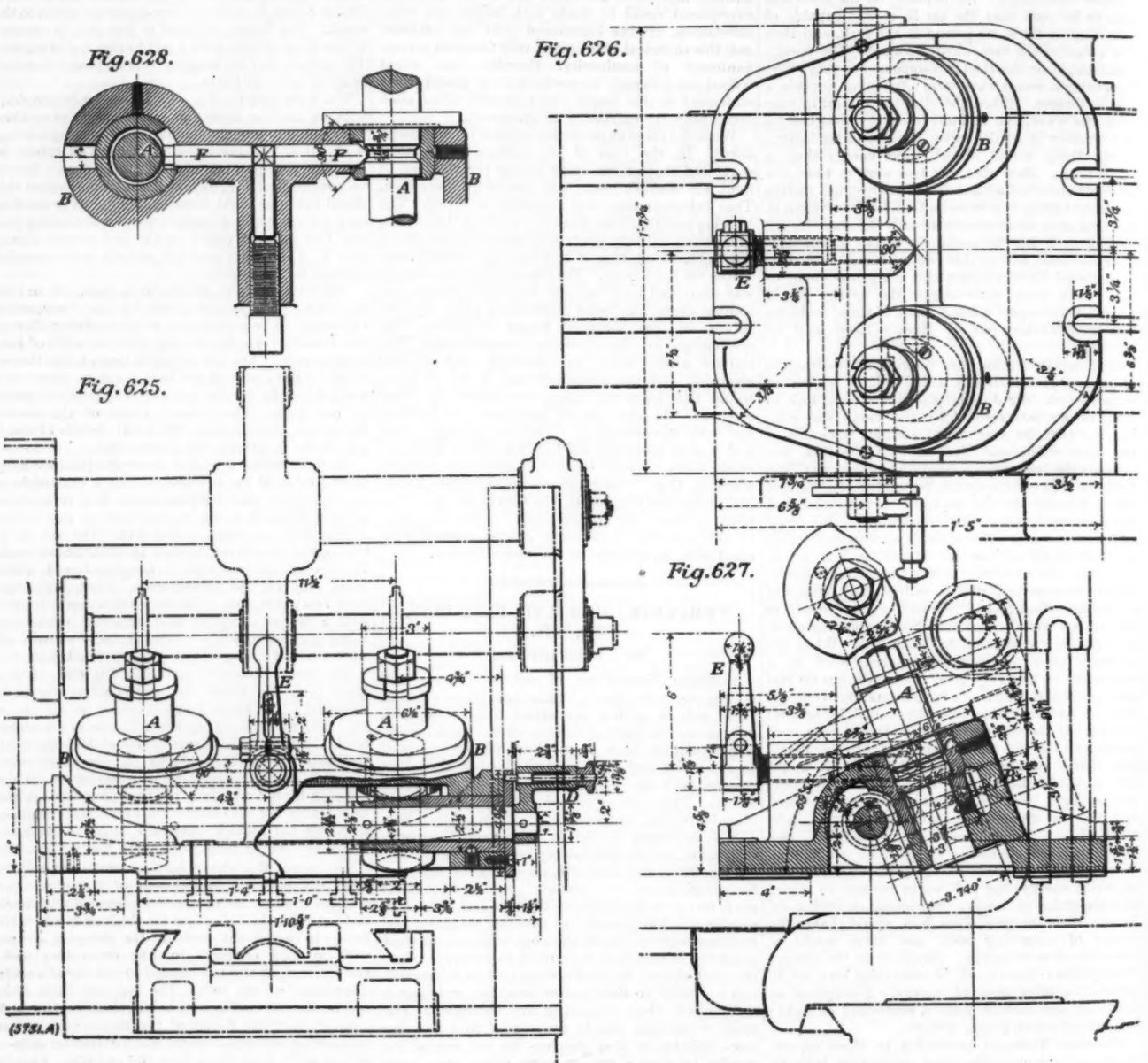
In these views a base A secured with four bolts to the table of the machine carries a centre-pin *a*, on which the work-holding turret B is rotated, to present the ends of the pairs of rods in turn to the milling cutters, shown in Fig. 642. The rods lie in seatings in the turret, located by their bossed ends. Each rod is covered with a clamping bar G, which bears only on the bossed ends. Each bar is set with two guide pins. The bars are secured in pairs with a pair of straps H near each end, each strap being tightened with a central bolt, thrown off with a coiled spring when the nut is slackened.

The base is shown separately in Fig. 632. It is a plain plate on which the work-holding turret is mounted. The turret being revolved on the pin *a*, Fig. 631, which is stepped into a hole in the centre of the base, is locked in positions of 180 deg. with the two hinged lock blocks E (compare with Fig. 633), on the centre of the base and turret. They are each hinged on a long pin that goes through the base, and which also carries the eyebolts F (compare with Fig. 634), which clamp the turret to the base. There are four of these bolts, with flange nuts.

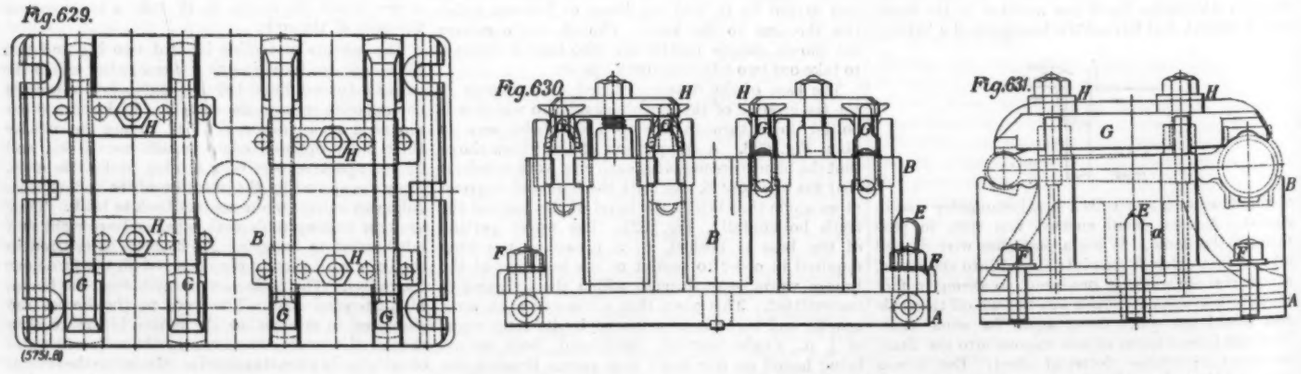
The turret B is shown by Figs. 635 to 639 apart from the base. A comparison of the plans and sections shows a hollow casting provided with open slot holes for the bolts, and for the lock blocks with bosses to receive the studs for the clamping straps, with locating elements for the connecting rods, and made right and left-handed to suit the alternate disposition of the rods. The big and little ends rest on concave seatings tooled for their location and support, and the flanks of the stems fit between upstanding portions—narrow zones of contact only—as seen in the plan views, Figs. 635 and 636. Details of the big and little ends are given, to the right, Figs. 640 and 641 respectively. The rods are held down with the clamping bars G, G, Figs. 629 to 631, across which the straps H, H, take a bearing near the ends of the rods.

The scheme of tooling is, that two big and two little ends are faced in one traverse, after which the turret is turned round 180 deg. and locked to present the opposite ends to the cutters. Eight cutters are mounted on an arbor, Fig. 642, to face the rods by their inner opposed edges, which are 1⅝ in., and 1½ in. apart respectively for big and little ends. They are spaced by the insertion of the collars seen. Adjacent cutters make contact back to back. They are true cutting tools with rake, and are right and left-handed to balance. Each cutter is secured in the body with a round pin flattened on the face next the cutter. The bodies are of mild steel, the blades of high-speed steel. The keys in the bodies are staggered in relation to the cutter blades so that though the teeth come even in the adjacent pairs of cutters, they are staggered in relation to the several pairs. The correct spacing of the blades is that

TEMPLETS, JIGS AND FIXTURES.

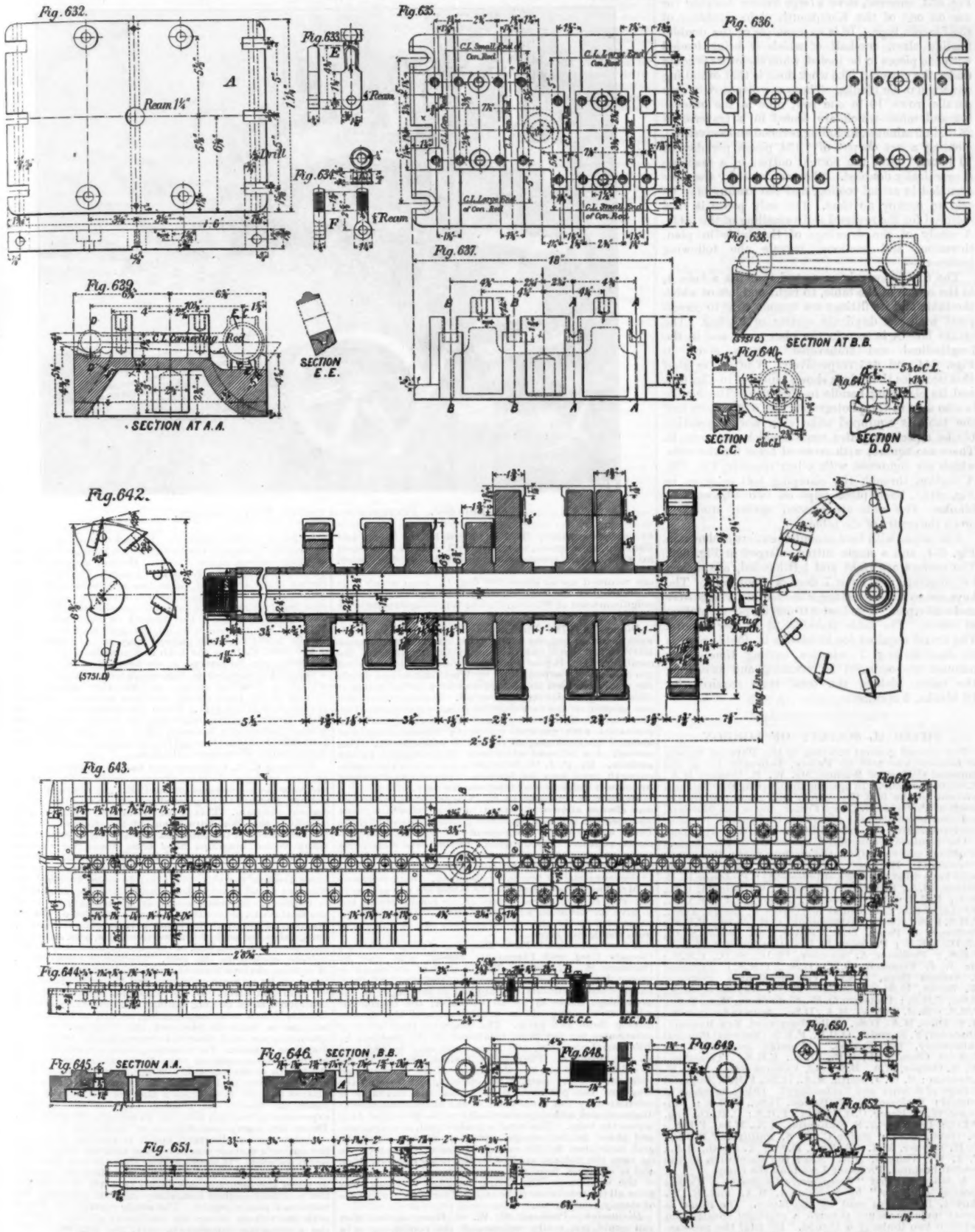


FIGS. 625 TO 628. FIXTURE FOR ROUGHING OUT THE TEETH OF BEVEL GEARS.



FIGS. 629 TO 631. FIXTURES FOR USE ON PLAIN MILLERS; THE KEMPSMITH MANUFACTURING COMPANY, MILWAUKEE, WIS., U.S.A.

TEMPLETS, JIGS AND FIXTURES.



FIGS. 632 TO 652. FIXTURES FOR USE ON PLAIN MILLERS; THE KEMPSMITH MANUFACTURING COMPANY, MILWAUKEE, WIS., U.S.A.

shown for the small bodies at the left, those at the right are spaced too widely.

The views, Figs. 643 to 652, and the photograph Fig. 653, annexed, show a large fixture designed for use on one of the Kempsmith plain machines of the Lincoln type. It is an example of the double-loading class, one-half of which is being loaded with the pieces to be tooled, while the other is going under the cutters. The work done is that of milling rectangular die blanks. These are disposed in two parallel rows, 10 in one row, nine in the other—hit and miss—which are tooled in a traverse of 25 in. in 9 minutes, including reversal and swivelling, yielding a net output of 1,134 pieces per day of 10 hours. Thus the normal output of a machine is practically doubled. The pace is set by the time occupied in actual tooling, and the loading may be said to occupy no time. The only pause is that required for the reversal and swivelling of the table. A study of the drawings of the table in plan, elevation, and sections, reveals the following features:—

The fixture swivels on a stud that fits a hole A, in the centre of the table, to right and left of which the table and its fittings are symmetrical to correspond with the duplicate system of loading. The centre hole A is seen in the plan view, and in the longitudinal and transverse sections given in Figs. 644 and 646 respectively. The centre stud that occupies the hole is shown enlarged in Fig. 648, and its clamping handle in Fig. 649. The handle is also seen in the photograph, Fig. 653. Each half the table is equipped alike with work-supporting blocks, and clamp plates, some of which are shown, B. These are square, with recessed holes for the nuts, which are tightened with a box spanner, Fig. 650. A section through the clamping bolt is given in Fig. 644. Each plate grips on two adjacent die blanks. The ends are located against studs set down the centre of the table.

The arbor with four mounted cutters is shown in Fig. 651, and a single cutter enlarged in Fig. 652. The cutters are right and left-handed, are nicked for slogging, and have 7 deg. of front rake. The keys are so cut as to stagger the teeth. The cutters make 53 r.p.m. The feed is 0·068 in. per revolution of cutter. The table travel is $3\frac{5}{8}$ in. per minute. The travel required for 19 blanks in double rows is 25 in., making 7 minutes cutting time. Two minutes are occupied in returning and swivelling the table, making the total time required for 19 blanks, 9 minutes.

PHYSICAL SOCIETY OF LONDON.

THE annual general meeting of the Physical Society of London was held on Friday, February 14, at the Imperial College of Science, Mr. W. R. Cooper, M.A., B.Sc., in the chair. In opening the meeting the chairman referred to the loss the society had sustained by the death of Professor G. Carey Foster, one of the founders, and mentioned that the president, Professor C. H. Lees, was representing the society at his funeral that afternoon.

The scrutators announced the result of the election of officers and council for the ensuing year: President: Professor C. H. Lees, D.Sc., F.R.S. Vice-presidents (who have filled the office of president): Professor R. B. Clifton, M.A., F.R.S.; Professor A. W. Reinold, C.B., M.A., F.R.S.; Sir W. de W. Abney, R.E., K.C.B., D.C.L., F.R.S.; Principal Sir Oliver J. Lodge, D.Sc., F.R.S.; Sir Richard Glazebrook, C.B., D.Sc., F.R.S.; Professor J. Perry, D.Sc., F.R.S.; C. Chree, Sc.D., LL.D., F.R.S.; Professor H. L. Callendar, M.A., LL.D., F.R.S.; Professor A. Schuster, Ph.D., Sc.D., F.R.S.; Sir J. J. Thomson, O.M., D.Sc., F.R.S.; Professor C. Vernon Boys, F.R.S. Vice-presidents: Professor W. Eccles, D.Sc.; Professor J. W. Nicholson, M.A., D.Sc., F.R.S.; Professor O. W. Richardson, M.A., D.Sc., F.R.S.; R. S. Willows, M.A., D.Sc. Secretaries (papers) H. S. Allen, M.A., D.Sc. (5, Presburg-road, New Malden); (Business) F. E. Smith, O.B.E., F.R.S. (National Physical Laboratory, Teddington). Foreign secretary: Sir Richard Glazebrook, C.B., D.Sc., F.R.S. Treasurer: W. R. Cooper, M.A., B.Sc. (82, Victoria-street, S.W. 1). Librarian: S. W. J. Smith, M.A., D.Sc., F.R.S. (Imperial College of Science and Technology). Other members of council: Professor E. H. Barton, D.Sc., F.R.S.; Professor W. H. Bragg, C.B.E., M.A., F.R.S.; C. R. Darling, F.I.C.; Professor A. S. Eddington, M.A., M.Sc., F.R.S.; D. Owen, D.Sc.; Major C. E. S. Phillips, F.R.S.E.; E. H. Rayner, M.A.; S. Russ, D.Sc.; T. Smith, B.A.; F. J. W. Whipple, M.A. After the conclusion of the general business, Professor Lees took the chair.

A paper, entitled "*Temperature Coefficient of Tensile Strength of Water*," by S. Skinner, M.A., and R. W. Burfitt, B.Sc., was read by the latter. The liquid is forced under pressure through a capillary constriction between two limbs of a U-tube. By trial the pressure is adjusted until the speed in the capillary is sufficient to produce rupture. This is judged by the sound and also the appearance. The whole U-tube is immersed in a bath, the temperature of which can be varied. Actual observations of rupture, velocity and temperature are recorded up to about 100 deg. C., from which it is deduced that the tensile strength becomes zero in the neighbourhood of 245 deg. C., which is in agreement with theory.

Discussion.—Dr. Vincent asked what arrangements were made to get the liquid back into the virgin state after it had been churned up by forcing through the capillary. Dr. Bryan asked how dissolved gas affected the results. In experiments by Worthington and others the water required to be very carefully boiled before it showed any tensile strength at all. Professor Lees also commented on the fact that the liquid experimented on here contained dissolved gas. In Worthington's experiments with gas-free water the tensile stress was about 2 atmospheres, as far as he remembered. This seemed of a different order from that obtained by the authors. Mr. F. J. W. Whipple asked where the tensile strength came into the formula. The diagram seemed to connect velocity and temperature only.

Mr. Burfitt, in reply to Dr. Vincent, said the liquid was always allowed to stand until all cloudiness had disappeared, and any dissolved gas was in equilibrium. There was no doubt the presence of dissolved gas promoted rupture. Worthington's method was static, and there was no danger of air getting in if the liquid was initially air free. In the present method it was impossible to prevent some air becoming dissolved. With reference to Mr. Whipple's comments, the tables are not primarily intended to give actual values of the tensile stress, but to give its variation with temperature. If desired, the value of C in the theoretical formula can be calculated from the figures given.

A paper, entitled "*Vector Diagrams of Some Oscillatory Circuits Used with Thermionic Tubes*," was read by Professor W. H. Eccles. The method of the crank or vector diagrams used commonly in the study of alternating-current circuits was applied in the paper to the assemblage made up of an oscillator, the thermionic relay maintaining it in oscillation, and the devices linking these two parts. The diagrams then serve as substitutes for the usual treatment of the problem by differential equation, and from them may be obtained all the formulæ. They have, besides, the advantage of exhibiting to the eye the phases of the currents and voltages in every part of the circuits. In forming the diagrams the potential drop across the oscillator is calculated by the usual rules of the alternating-current diagram, and added geometrically to the potential drop across the tube. This total is made equal, in magnitude and phase, to the voltage applied at the instant to the grid multiplied by the voltage factor of the relay. In its turn the voltage applied to the relay depends upon and is obtained from the current running in a portion of the oscillator. The fitting together of these lines gives all the conditions to be satisfied for the maintenance of steady oscillations.

Discussion.—Professor G. W. O. Howe agreed that you could not really understand the conditions in a circuit unless you were able to put down the currents and voltages in a vector diagram. He had attempted himself to simplify Vallauri's treatment for students, but without as much success as Dr. Eccles. He had usually looked at these circuits from this point of view: The oscillatory circuit apart from the valve has a certain equivalent resistance. To maintain oscillations the equivalent of a negative resistance must be introduced. There are two ways of varying the current in the bulbs; the P.D. on the terminals or on the grid may be varied. In the latter case the current may be increased even if the total P.D. on the bulb is diminished, and if this condition can be arrived at we have the equivalent of a negative resistance to the oscillations. You have to arrange a coupling device so that the variations of current in the plate circuit produces suitable variations of potential of the grid. From the characteristic of the plate circuit you can determine the critical value of the mutual inductance between plate and grid circuits to give the equivalent negative resistance necessary for maintenance of steady oscillations.

Professor C. R. Fortescue said the method of approach appears to be a distinct advance, in that the idea of the tube as a generator of an E.M.F., $g\,E\,g$, enables a voltage diagram to be plotted instead of the more usual current diagram. This is an undoubted advance, and simplifies the final adjustment of the diagram to suit the conditions of the tube and circuit. At various times many vector diagrams have been drawn for various oscillatory circuits; and in the whole the results have hardly come up to expectations. There appears to be three reasons for this, viz.: (*a*) In order to draw the diagram at all a very clear insight into the conditions is required. In other words, it is necessary to know the final result before the diagram is completed. In the diagram of Fig. 3 of the paper it is necessary to know, firstly, that the angle θ is a positive angle, and, secondly, that the effective E.M.F. of the tube is in phase with the voltage applied to the grid. The latter condition is, of course, obvious from the action of the tube, but the former is by no means obvious, and has to be discovered by trial and error. If, for example, the current I is considered to be flowing through the inductance, then θ must be taken as an angle of lag, as will be found if an attempt is made to plot out this diagram. (*b*) The quantities are such that it is impracticable to plot the diagrams to scale. For example, if the numerical values of the first example on page 3 are taken, the ratio of the length of the line O U g of Fig. 3, to the length D Q is of the order of 1 to 500,000. Actually, if Fig. 3 is plotted to scale, it becomes a diagram vertically up and down the board. (*c*) Finally, there is the common experience of the sign difficulty in drawing the diagrams. There are many possibilities of confusion with the ordinary current diagram, but it is possible that with the author's voltage diagram these troubles will be very much reduced. It would appear that the true function of these diagrams, when numerical values are applied or when the diagrams are drawn to scale, is to justify the practical method commonly used of regarding the valve as a power supply. The anode current is in phase with the voltage across the oscillatory circuit. Taking the alternating components only, the product of the anode current and the circuit voltage gives the power

TEMPLETS, JIGS AND FIXTURES.

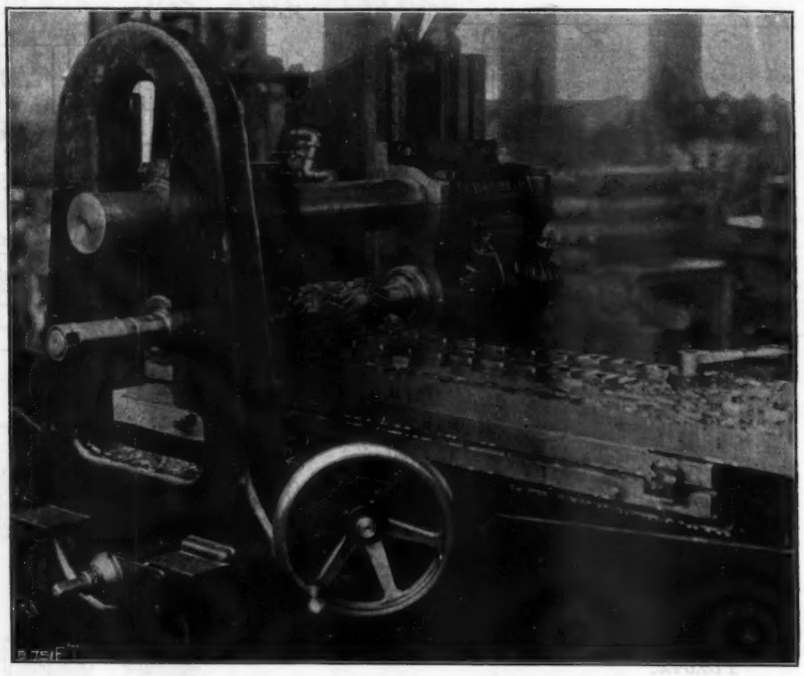


FIG. 653. FIXTURES FOR USE ON PLAIN MILLERS.

supplied to the circuit. The anode current depends upon the anode and grid voltages, i.e., $i = h_a\ e_a + h_g\ e_g$, as given on page 1 of the proof of the paper. To within a small percentage this power is absorbed by the circuit losses. If R + S is the effective resistance of the oscillatory circuit, then for the oscillations to be maintained or built up, the power supply from the valve must be equal to or greater than the $J^2(R + S)$ loss. This method of dealing with the problem has many practical advantages, and has been in use for some years. Hazeltine has described, in the Proceedings of the American Institute of Radio Engineers, the application of the method to various circuits, notably the circuit in which a condenser is connected across the grid inductance h. It is very well known that the author of this paper has had experience of many other circuits and applications of three electrode relays, and it is to be hoped that he may be able to give to the society further papers on this same subject. In particular, a vector treatment of the De Forest ultraudion circuit would be of great interest, as this circuit is one which has presented very great difficulties when any attempts have been made to calculate the condition for instability.

Mr. J. Nicol asked if there was any lag between the voltage applied to the grid and the effect on the current in the valve. Dr. D. Owen said it was assumed that the action of the valve was an amplification of voltage. Actually what happened was a variation in the resistance of the valve. It seemed rather remarkable that this should be regarded as a voltage effect. He did not like Professor Howe's idea of a negative resistance, as such a conception had no physical significance. A negative value of $d\ V/d\ C$ was by no means the same thing as a negative value of V/C, which would be required before we could talk of a negative resistance. Did the author find it satisfactory to treat the quantity h_a as a constant?

Mr. F. E. Smith thought the paper of great value. He agreed with Professor Fortescue that a great amount of interesting work was still to be done in connection with these problems. Captain Turner referred to a sentence occurring in the section dealing with a particular case: "It is noteworthy that . . . no resistance." This seemed to imply that an infinitesimal change in E would produce a finite change in the steady component of the anode current.

Dr. Eccles, in reply, said that he did not think vector diagrams were ever used quantitatively. They were mainly used to derive a formula, and the scale of the vectors was immaterial. As regards lag, he was not aware of any definite knowledge on this point, but the fact that nowadays waves of 30,000,000∞ per second were obtained showed that the lag must be very small. He thought it was justifiable to assume it zero in slow circuits. The conception of the valve as a voltage amplifier seemed a difficulty; but if we vary the resistance of one part of a circuit containing a fixed E.M.F. it is clear that the P.D. on the remainder of the circuit will also vary; so that the varying resistance can be regarded as a source of varying E.M.F. applied to the remainder of the circuit. The quantity h_a was not constant. As regards Captain Turner's point, he was referring here to a case in which there was no resistance in the inductance circuit.

A paper, entitled "*A Small Direct-Current Motor Using Thermionic Tubes instead of Sliding Contacts*," by Professor W. H. Eccles and Mr. F. W. Jordan, was read by the latter. In this motor the rotating part is an ebonite disc with iron teeth on its periphery, and the stationary part comprises two electromagnets with their poles close to two teeth. One electromagnet is connected to the grid of a thermionic relay, the other is included in the plate circuit. When during rotation a tooth passing the grid magnet induces a voltage in its winding the consequent transient increase of current through the other magnet causes this magnet to exert a pull on the tooth approaching it. We thus have a small motor without commutator or spark which may under no-load be driven up to a speed of 4,000 r.p.m. to 6,000 r.p.m. from the lighting supply.

INJECTION OF WATER INTO INTERNAL-COMBUSTION ENGINES.

To the Editor of Engineering.

SIR,—In several papers I see advertisements relating to crude oil engines containing the misleading statement that the use of water injection for obtaining increased power has been proved to be attended with injurious results to the engine because the sulphur present in the oil combines with the water and forms sulphuric acid, which rapidly eats away cylinder walls, pistons and piston rings.

The fact is, however, that the worst fuel does not contain more than a maximum of 2 per cent. of sulphur and at the same time contains at least 6 per cent. of hydrogen. This hydrogen combines with oxygen of the air and forms water, a part of which latter combines with the sulphur and more oxygen, thus forming sulphuric acid, according to the equation:

$$2S + 3O_2 + 2H_2O = 2H_2SO_4.$$

So 4 parts of hydrogen form sulphuric acid by combining with 64 parts of sulphur and 128 parts of oxygen, the atomic weights of the said elements being (rounded off) 1·32 and 16 respectively. Whereas the fuel does not contain more sulphur than one-third of the weight of hydrogen contained in it, it is clear that it is impossible that injection of water can cause the formation of more sulphuric acid than is formed if no water at all is injected. In using oil containing sulphur it is advisable to avoid the use of copper or copper alloys, not only in the engine proper but also in the fuel pump and all parts coming into contact with the fuel or the burnt gases.

The injection of water into internal-combustion engines is very useful, if it is arranged in a judicious way, because it greatly improves the combustion process by its catalytic action and in proportion as combustion pressure is produced earlier during the working stroke, the mean pressure, of course, is higher, so more power is obtained from the same quantity of fuel. The water vapour prevents the combustion from proceeding slowly and tardily, and obviates the possibility of formation of soot and other products of incomplete combustion. This catalytic acceleration of combustion processes by water vapour is very remarkable, and as generally little attention is paid to it, a few important and interesting facts may be mentioned for the benefit of some of your readers, for the better understanding of its extraordinary value.

Dixon observed that a completely dry mixture of carbonic monoxide and oxygen cannot be ignited, neither by a red-hot spiral nor by induction sparks. After adding water vapour, however, the mixture becomes explodable. A carbonic mono-oxide flame goes out in dry air. Dry nitro-cellulose detonates with a velocity of 3,750 m. per second, whereas wet nitro-cellulose burns with a speed of 6,000 m. per second.

In introducing water vapour into the combustion process of hydrocarbons, it is resolved into its constituent elements by the heat and enriches the heavy hydrocarbons with hydrogen, thus effecting the establishment of hydrocarbons containing more hydrogen and liberating at the same time oxygen, which latter, together with the oxygen contained in the air, afterwards combines with great rapidity with the fuel made much more easily inflammable by the enrichment with hydrogen.

In hot-bulb engines with injection of water, in order to keep the temperature of the hot bulb below its limit, there is an important improvement of the combustion process, if too much water is not injected. That there are hot-bulb engines in which the introduction of water does not give satisfaction, is the consequence of the injudicious manner in which the object aimed at is tried to be attained. It is self-evident, indeed, that the mixing of water with the air while being drawn in, usually without any automatic regulation, must lead to troubles. The water is injected in the form in which it is required, not in a liquid state on the top of the piston or below the piston—or, in two-cycle engines with crank-case scavenging air, directly into the crank-case, &c.—whilst the quantity is seldom exactly what is required, even if somebody attends to the water drip and tries to regulate it.

The quantity of water must be exactly supplied, preferably under the control of the governor, i.e., in proportion to the load of the engine, in other words, in proportion to the quantity of fuel. Further, it must be injected at the proper time, where it is wanted, and must be converted into steam.

Yours faithfully,
A. F. VAN AMSTEL.

Amersfoort (Holland), March 11, 1919.

"COAL SAVING AND SCIENTIFIC CONTROL OF STEAM BOILER PLANT."

To the Editor of Engineering.

SIR,—It may assist many of your readers to get rid of the inconsistencies of their text-books if the connection between the rate of combustion and the proportions of steam boilers is clearly illustrated. In response to a request from another quarter I jotted down the detailed calculation below. It will perhaps be received in some quarters with the same mixed feelings as was my first letter on this subject, but my nationality, by tradition, precludes any intention of perpetrating a joke.

Lancashire boiler to evaporate 5,848 lb. of water per hour under natural draught on coal fuel of a calorific value of 13,500 British thermal units per pound, and to have a guaranteed thermal efficiency of 80 per cent. Working pressure, 185 lb. per square inch. Feed temperature, 60 deg. F.

$$\frac{1,170}{0·8} = 1,462 \text{ British thermal units per pound of water.}$$

$$\frac{13,500}{1,462} = 9·2 \text{ lb. of water per pound of coal.}$$

$$\frac{13,500}{54} + 12·4 = 262·4 \text{ cub. ft. of gases per pound of coal.}$$

$$\frac{1,462}{262·4} = 5·57 \text{ lb. of water per square foot of heating surface.}$$

$$\frac{5,848}{5·57} = 1,048 \text{ sq. ft. of heating surface.}$$

$$= 8 \text{ ft. } 6 \text{ in. by } 30 \text{ ft. boiler.}$$

$$\frac{5,848}{9·2} = 636 \text{ lb. of coal per hour.}$$

$$\frac{1,048}{50} = 21 \text{ sq. ft. of grate area.}$$

$$\frac{636}{21} = 30·3 \text{ lb. of coal per square foot of grate area.}$$

$$1,462 \times 5·57 = 8,143 \text{ British thermal units per square foot of heating surface.}$$

$$54 \times 12·4 = 669 = \text{The rate of combustion in British thermal units per pound of air used.}$$

If the above boiler is operated under forced draught at a rate of firing equal to 90·9 lb. of coal per square foot of grate area, then its output will increase, but its thermal efficiency will decrease in the following ratio.

$$\frac{90·9}{30·3} = 3 = \text{ratio of increase in rate of firing.}$$

$$\frac{80}{\sqrt[3]{3}} = 55·4 \text{ per cent. thermal efficiency.}$$

This rate of increase in firing is, of course, beyond anything attempted with Lancashire boilers, but is quite common in locomotive boilers, and is chosen purposely to illustrate the effect of that.

The increase in output is as follows:—

$$\frac{9·2 \times 55·4}{80} = 6·37 \text{ lb. of water per pound of coal.}$$

$$6·37 \times 636 \times 3 = 12,153 \text{ lb. of water per hour.}$$

In conclusion—so long as the ratio of total fuel to heating surface remains unaltered, the ratio of heating surface to grate area may be altered to suit different classes of fuel of equal calorific value. So long as the total heat supplied remains unaltered the same applies to fuels of different calorific values.

Yours truly,
JAS. DUNLOP.

190, Bellfield-street, Dennistoun, Glasgow,
March 15, 1919.

To the Editor of Engineering.

SIR,—As the calorific value of coal varies from 9,500 British thermal units to nearly 15,000 British thermal units per pound, the weight of air for combustion varies proportionately, or nearly so, and it is common knowledge that 10·7 lb. of air per pound of coal is the average weight for complete combustion. For simplification, however, the majority of engineers take the round number 12 lb. as the theoretical weight per pound of coal, 50 per cent. additional air giving the weight, 18 lb., required for good practical working, and it is in this way the "hoary 12 lb." was introduced.

Mr. Dunlop, in his letter of Saturday week, gives for maximum efficiency 620 heat units per pound of air, and further states that for all practical calculations combustion is theoretically complete at an assumed rate of 1,500 British thermal units per pound of air used.

Working on this rule, and taking coal with a calorific value of 10,000 British thermal units, the theoretical weight of air per pound of coal will be 6·6 lb., plus 120 per cent. for maximum efficiency; this equals 14·31 lb. of air per pound of coal; with coal of 12,000 units calorific value the theoretical weight of air is 8 lb., and for maximum efficiency 8 lb. plus 120 per cent. = 17·6 lb. of air per pound of coal, and when the calorific value is 14,000 British thermal units the air supply is 20·46 lb. per pound of coal.

In my previous letters I have given as the theoretical weight of air 12 lb. per pound of coal of the same calorific value, i.e., 12,000 British thermal units plus 50 per cent. excess air, which gives 18 lb. of air per pound of coal, as against Mr. Dunlop's average for three grades of 17·4. Another case of "A rose by any other name is just as sweet."

Yours faithfully,
W. H. CASMEY.

Milnthorpe, Wakefield, March 18, 1919.

NAVAL ENGINEERS.

To the Editor of Engineering.

SIR,—Beyond the matters already touched upon in this correspondence there are others of equal or greater importance which it is proposed to glance at. You will probably agree, Sir, that it is a remarkable state of affairs that the largest and most important engineering concern in the world—the British Navy—should at this time of day be without a plan, at once comprehensive, adequate and satisfactory, for training its professional engineering staff. Yet such is the case, and this condition of things is the more remarkable inasmuch as the Admiralty have for a century or so been among the pioneers of technical education, and that it is to their schools of naval architecture and engineering that the nation has been indebted for the services of such as Reed, Barnaby, Watts, Sennett, Durston and Oram, to say nothing of a large number of officers now holding important posts under the Government or in our great shipbuilding and engineering works. Under the *régime* of Sir William White and his predecessors the education of naval architects reached a very high standard, and the benefit to the country has been immeasurable. Much the same may also be said of the training of engineers in the dockyards and at South Kensington, Greenwich and Keyham. But while the organisation of the education and training of naval architects has been mainly in the hands of naval architects, the training of engineers has not been to the same extent in the hands of engineers, and it is due to this more than anything else that to-day the Navy is without a high school of engineering or a body of young officers being adequately trained for ultimately filling the higher professional positions in the engineering department.

The first naval engineer officer entered the service in 1837, the year the Steam Engineering Department was initiated at Somerset House. He and his immediate successors both ashore and afloat, were drawn from the workshops of Boulton and Watt, Napier, Maudsley, and other famous firms. As the domain of engineering extended, a system of training engineer students in the dockyards was established, and it was while this was in vogue that the Royal School of Naval Architecture and Marine Engineering was founded at South Kensington. The work of this Institution was, in 1873, transferred to the Royal Naval College at Greenwich, where the advanced courses in naval architecture and engineering have since been given. The dockyard system of training engineer students was superseded in 1878 by the

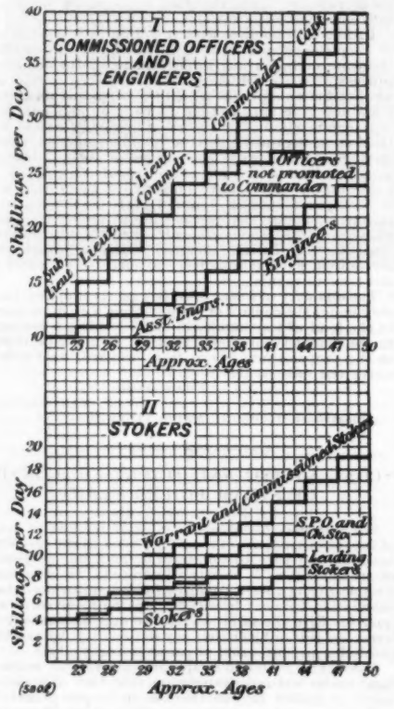
"Marlborough" scheme, which in turn gave way to the Keyham College scheme of 1880. If it be that nothing succeeds like success, then judging by results there never was a more successful engineering school than Keyham College, for just as our great admirals and captains are the products of the famous old "Britannia," so the great majority of the senior naval engineer officers of to-day are the products of the Royal Naval Engineering College which, with all its shortcomings, has repaid the country a hundred-fold.

This being granted, it may be asked why, then, was so successful an institution discarded. Was it out of date? Did it not meet the needs of the time? Were the students weighed and found wanting? The answer is, of course, well known. The engineer officer of twenty years ago had reached a stage in his development that called for further readjustment in his status aboard ship, and sooner than grant the concessions which were pressing, it was decided to abandon the separate training of engineer cadets, to close the college, and endeavour to graft the duties of an engineer on to those already performed by officers of the upper deck branch. There was much fine talking about common entry, common training, interchangeability, reversion to command and other theories which in the end have certaitly failed to produce the desired effect, and the engineering training now given deserves no other designation than patch-work. Not one engineer in a thousand believes the Osborne scheme of training had for its object increase of engineering knowledge or a higher training for engineers themselves, for while thousands of pounds were spent on workshops and tools for school boys of 12, 13 and 14 years of age, the higher professional work was neglected. The last engineer cadets entered Keyham about 1906, the college was closed in 1910, and since then there has not been one single officer trained in readiness to follow in the footsteps of those who are known as the professional officers of the branch. The organisation of a quarter of a century was ruthlessly scrapped, a capable staff dispersed, and whatever there was of tradition and *esprit de corps* was thrown away. The result of this is likely to be felt in naval engineering matters for many years to come.

Though it may be said that criticism of the Osborne scheme of training has almost been ridden to death, it is perhaps worth while inquiring why Osborne has not produced an adequate supply of engineer officers? The first consideration, is that engineering is essentially a middle-class profession, and many of the Osborne boys would never under any circumstances seek their fortune on the starting platform. Then, too, though compulsory allocation to the executive, engineering and marine branches was to be the order of the day, who ever thought that was practicable? The thing had to be voluntary, and the results of the voluntary system were obvious from the first. For do what you will, offer what inducements you like, engineering in the Navy can never compete in attractiveness with the upper deck and the reference of your correspondent, "A Naval Engineer," to the absence of decorations on the coats of the engineer officers at Osborne is but one instance of what is inevitable. Those before the foot-lights receive the applause; those behind the scenes do but hear it. A distinguished admiral once said that in the Navy praise should be never expected, seldom given, but always deserved; and it is a saying engineer officers should take to heart. Bearing all this in mind, it may be said that the profession of a naval engineer has many attractions of its own, the importance of the engineer is fully recognised by the majority of commanding officers, it is his own fault if he is not treated with due deference, and save for the consideration that for the very ambitious there is only one job in a ship worth having after a man has turned forty, there is no reason why any youth of education and ability should hesitate to enter its portals.

In connection with the foregoing there are those who, having the future efficiency of engineering in the Navy at heart, are naturally asking, if Osborne is failing to give the proper supply of engineer officers, where then are these officers to come from, how are they to be trained, and what is going to be done to weld together into a homogeneous corps the engineer-lieutenants, the lieutenants (E) and the temporary service officers? These, it is submitted, are questions of capital importance, for it is quite time that the whole matter was placed on a sound basis and freed from the periodical upheavals which have occurred in the past. And the first and most important suggestion made here is that the urgent need of the time is that the Royal Engineering College at Keyham should be reopened as a thoroughly up-to-date school of engineering, which in the future should become to the engineer officer what the "Vernon" is to the torpedo officer and the "Excellent" is to the gunnery officer. It should, needless to say, be under the direction of a senior engineer officer of distinction, who should be supported by a staff of professors and engineer officers as instructors. The old Keyham system was perhaps as good a system as was in existence then, and now that the college has been brought up to date in the way of accommodation and that experimental plant has been installed, there is no reason why it should not again take its place among the foremost of our technical institutions. One of the advantages of the college is that it enables its students to obtain their practical experience under the tuition of thorough-going skilled workmen in the shops of the Engineering Department of Devonport Dockyard, an advantage inestimable to those who are likely to be the future managers and under managers of similar departments. The number of students necessary to be trained ultimately to fill the engineering posts at the Admiralty, on overseeing duties, in the dockyards and in the Fleet, is easily calculated, and to put the number at 40 per annum is by no means overstating the case. A course of three or four years should suffice if the post graduate courses at Greenwich are maintained. The entry should again be by open competitive examination at about the age of 16 or 17, a certain number of places being reserved for cadets from Dartmouth who desire to become engineers, and what is also eminently desirable, there should be an annual competition for scholarships at the college, among the boy artificers under training in the "Fisgard" and "Indus." It has been a reproach in the past that naval engineers have added comparatively little to the literature of engineering, and in this connection encouragement should be given to the study of foreign technical literature, especially French and German.

Bound up with the reorganisation of engineering training is that of the amalgamation of the existing officers of this branch into one corps with the same rates of pay, the same titles and the same uniform. Surely it cannot be the intention to perpetuate the present inequalities and anomalies. Whether they are all called lieutenants (E) or engineer-lieutenants matters little, but the differences should be removed. The temporary service officers, too, should be absorbed into the permanent lists as far as they are required. There are engineer commanders serving now who, because their names were on a temporary service list for six years, will draw a reduced pension, and it behoves the new temporary officers to see they are not penalised in the same manner. It may perhaps be doubted whether the



rather extravagant rates of pay offered to lieutenants (E) will be given to all, but perhaps the Jerram Committee and the Ladies Committee on Naval Officers Pay will obtain some proper adjustment in this matter. It is to be hoped they will. In the old days the engineer officer received a good deal less than his fellow officers on the upper deck; now he appears likely to get a great deal more. Neither position seems to be right, and there is much to be said for the proposal to give all officers of the military branch the same daily rates of pay, while retaining the small additions given as charge pay, senior engineer's allowance, navigation allowance, gunnery allowance, &c.

The officers to whom reference has been made so far are those who are from the first recognised as the professional officers who, while having had a fair training in workshop practice are rather engineers by profession than engineers by trade. It is proposed now to touch upon one or two matters concerning the engineers by trade—the engine-room artificers, who really constitute the skilled workmen of the branch. Introduced into the service in 1868 the engine-room artificers have been among the hardest worked men in the Navy, and their services have been of the very greatest importance. During the war the engineering branch as a whole may be said to have carried the Navy on its back, and a very great proportion of the work entailed has fallen to the lot of the artificers. Though it took thirty years—from 1868 to 1898—for even the warrant ranks to be opened to this class, yet to-day the Navy List contains the names of some hundreds of engineer-lieutenants, mates (E), chief artificer engineers and artificer engineers, all of whom began their career either in the "Fisgard" or "Indus," or entered direct from some outside engineering firm. Both in education and training this class has been on the up grade, and to-day their demand is for improved status, better living and messing accommodation, higher pay and pensions and, further, more opportunity to rise. The suggestion made above that the boy artificers should be eligible for competing for scholarships will commend itself to most engineers, for natural ability should be given a chance at an early age. The effort to gain an improved status for all artificers—the proposal is that they should be called assistant engineers and engineers, instead of E.R.A.'s and C.E.R.A.'s—is strengthened by the fact that all their fellows in the mercantile marine have been recognised as officers. Beside this, though war is supposed to be the opportunity of the professional fighting man, the artificers say that the proportion of promotions which have come to them has by no means been what it should have been, and that there are in their ranks many men of ability and experience quite fitted to occupy the positions filled by the entry of engineer-lieutenants for temporary service. That there is justice in the demand for a higher standing than that of chief petty officer must be conceded when it is recalled that many artificers are in charge of the machinery of submarines and small ships, many do senior engineers' duties in destroyers and many are the actual watch-keeping officers in light cruisers and other ships, all duties calling for tact, knowledge and experience. That only a small proportion of them can eventually reach commissioned rank is obvious from the first, but it is worth nothing that they desire that all promotion should be by severe competitive examination.

Among the questions affecting the engine-room artificers is the thorny one of the mechanicians. This is a question of the dilutee, which touches a principle in trades unionism. The mechanicians are supposed to be the pick of the stokers, who at a fairly advanced age are withdrawn from service and for two years given a training which makes them more or less fit to do the work of an E.R.A. to the extent that at one time three mechanicians were calculated to be equal to two E.R.A.'s. If a Government thinks it in the national interest to do this it is difficult to see why men in a democratic age should object, but if the stoker can be so favoured, why should not the E.R.A. go to college for two years and, applying the principle elsewhere, why not attempt to turn sick-berth stewards into assistant surgeons? That commercial undertakings do not proceed on these rather costly lines is easily understood, and it may be that in the lean years in front of us some of this expensive and unnecessary training will have to be abandoned. Then, too, when the mechanician was introduced Mr. McKenna apparently promised that the prospects and promotion of E.R.A.'s should not be affected. To-day the E.R.A.s' point to the hundred or so warrant mechanicians and ask what is the use of such promises? They maintain that there is a proper avenue of promotion through the grades of leading stoker, stoker petty officer, chief stoker, to warrant stoker, and lieutenant, and that lieutenants so promoted are quite as capable of supervising the stokers in barracks and elsewhere as are the lieutenants promoted from seamen.

Little will be said here as regards the pay and pension of the various sections of the engineering branch. Pay in the Navy is a very complicated affair. It is all based on ha'pennies and pennies a day, and except to an accountant officer is as much a puzzle as the weights and measures of China. A penny a day for this and a penny a day for that has resulted in a mass of regulations worthy of the palmiest days of the Circumlocution Office, and what could be exhibited on a dozen sheets of squared paper occupies many pages of print. It was a welcome sign, however, that the recent bonuses were calculated in shillings and sixpences, and it may be that a great deal of the accumulation of years will be swept aside, so that he who runs may read. Before closing this letter it may, however, be permitted to summarise the proposals which have been put forward here with no other object than that of increasing the efficiency of the engineering branch of our great Navy.

The suggestions are:—

1. The reopening of the Royal Naval Engineering College at Keyham as the principal school of engineering for the Navy.

2. The revival of entry of engineer cadets by competitive examination due regard being paid to the ambitions of the cadets at Dartmouth and of the boy artificers in the "Indus" and "Fisgard."

3. The amalgamation into an homogeneous corps of the various types of engineer officer now in the service, with equal rates of pay, corresponding titles and similar uniform.

4. The improvement of the status of the engine-room artificers to bring them into line with their fellows in the mercantile marine.

5. The replacement of the mechanician scheme of promotion by promotion through the rank of chief stoker.

6. Readjustment of pay, pensions and conditions of retirement of all officers and men of the branch.

Yours, &c.,
"AN ENGINEER."

P.S.—Though believing that the efficiency of any department depends more on ability, training and status than on salaries, at a time when most folk seem to consider the want of money the root of all evil, on second thoughts it may be well to append a few notes on the question of pay, especially as it appears that for the first time in history the pay of both officers and men in the Navy is to be dealt with in a fairly generous manner.

The simple diagrams given above, illustrate a system of pay charts which might be adopted for all the various ratings. There are, it may be presumed, equations to which all curves of pay should conform if ambitions are to be stimulated, services rewarded and needs satisfied.

Based on purely assumed data, the charts given indicate a system of triennial increments. To your readers they will be self-explanatory, and each for

himself can raise or lower the lines of pay as he thinks fair and just.

By a series of similar diagrams, and by fixing the proper ratio of pension to pay for various ages of retirement—say ½ at 45, ⅔ at 50, and ¾ at 55—a great many complications could be removed. The matter of reward for the men's "V.G." time is readily settled by making it a condition that each increment of pay should only be given after a period of three years V.G., the increase of pay and pension thus automatically adjusting themselves. The pay suggested is that of a daily rate only, and does not include charge pay, senior engineers' allowance, hard-lying money, submarine or tropical pay, &c.

SLIDING FRICTION IN BALL BEARINGS.

TO THE EDITOR OF ENGINEERING.

SIR,—Having had several years practical experience with ball-bearing manufacturers, both on the Continent and at home, I read Mr. Arvid Palmgren's article in your issue of February 28 with much interest.

1. The question of contact of elastic solids is always difficult to deal with from a mathematical standpoint. Many theoretical hypotheses have to be introduced, and the mathematics become unwieldy. For comparisons of load-bearing capacities this may be necessary. But surely the introduction of still more hypotheses to deal with the absorption of power is unnecessary. That these assumptions are not warranted may be judged from the following. Your correspondent's final deductions include the statement that the power absorbed by an annular bearing of 50 mm. bore, carrying a load of 500 kg. at 1,000 r.p.m. = 308·6 kg. mm./sec. This gives an "effective coefficient" of friction reckoned on the shaft diameter of :—

$$308{\cdot}6 \div \left\{ 500 \times \frac{22}{7} \times 50 \times \frac{1000}{60} \right\}$$
$$= 0{\cdot}0003.$$

This does not even approach the magnitude of the results found on test. Any reputable English manufacturer can produce test results by the National Physical Laboratory in confirmation of my statement.

So much, then, for the validity of the theoretical assumptions made by your contributor in his endeavour to show, theoretically, that the spherical bearing run with less friction than the annular type.

2. It is conceded that, other things being equal, a ball will run with less friction in a groove of large radius than in a groove of small radius. This, however, is bought at the expense of decreasing the load-bearing capacity. For instance, a ball running on a flat plate manifestly loses less by friction than a ball running in a groove of its own radius. But the load-bearing capacities are still less comparable. Professor Stribeck's classic experiments showed conclusively that there is a ratio for the radii of ball and groove which allows of the maximum load with the minimum friction. These experiments formed the basis for manufacturers, who, no doubt, modified the ratio to suit the material they used. In any case, the ratio does not allow of a groove radius as large as is found in the spherical bearing, if the load-bearing capacity is to be maintained.

3. However, the proviso contained in (2) does not hold, for conditions are indeed different in the spherical and annular types of bearing. In the former, the line joining the points of contact on the ball (which is at right angles to the principal axis of rotation of the ball) is not at right angles to the axis of rotation on the bearing. This is the fundamental principle which determines whether a ball bearing causes the balls to spin, and excluding the effect of the cage and quantities of the second order of smallness, it is spinning action which is solely responsible for friction in ball journal bearings. Fig. 1 indicates what is meant, and Fig. 2 is referred to in the following simple geometrical investigation.

Fig. 2 represents a ball in contact with ball races of any radius greater than that of the ball, and with the line P Q, joining the main points of contact on the ball at an angle α with the axis of the shaft.

Let the inner race of the bearing be considered stationary, and the outer race revolving. Then the primary movements of the ball, if point contact is considered, are a rotation about the axis of the shaft, and a rotation about an axis at right angles to P Q. However, in practice contact is over a surface, not a point. Let $a\,b$ represent the limits of the contact surface on the outer case and $c\,d$ on the inner race.

Let ω_1 = Angular velocity of outer race about the axis of the shaft.
ω_2 = Angular velocity of ball about the axis of the shaft.
ω_3 = Angular velocity of ball about its own axis.

If no friction is to ensue, then the points a and b on the ball must have the same velocity as the same points on the outer race, and similarly for the points c and d and the inner race.

Drop the perpendiculars shown on the two axes of rotation, then :—

The velocity of point a on the race $= \omega_1 \times ae$.
The velocity of point b on the race $= \omega_1 \times bf$.
The velocity of point a on the ball $= \omega_2 \times ae + \omega_3 \times ai$.
The velocity of point b on the ball $= \omega_2 \times bf + \omega_3 \times bj$.

∴ for no friction :—

$$\omega_1 \times ae = \omega_2 \times ae + \omega_3 \times ai \quad . \quad . \quad (A)$$

and

$$\omega_1 \times bf = \omega_2 \times bf + \omega_3 \times bj \quad . \quad . \quad (B)$$

Now $a\,b$ is small compared with the radius of the ball. Therefore, neglecting magnitudes of the second order of smallness $ai = bj$. Whence, substracting (A) from (B) :—

$$\omega_1 \times (ae - bf) = \omega_2 \times (ae - bf).$$

Thus, as ω_1 does not equal ω_2, $ae = bf$.

This condition clearly cannot be met unless $\alpha = 90$ deg., *i.e.*, it is not met in the double row spherical bearing, but is met in the annular type.

A similar action takes place at the points c and d.

The effect of this failure of the double-row spherical bearing to meet the fundamental condition for the elimination of sliding friction is to set up a rotation of the ball about the axis P Q. This accentuates the sliding friction in this type of bearing, and the effect is familiar to most engineers as "spinning," the cause of otherwise unaccountable wear in wrongly-designed ball bearings.

4. Your contributor's article, in one of the two places in which he forsakes his theories for practice, gives confirmation of the above. On page 291 he states that ω_s (the angular velocity of spinning about the axis P Q) has been found to be 0·45 per second in the

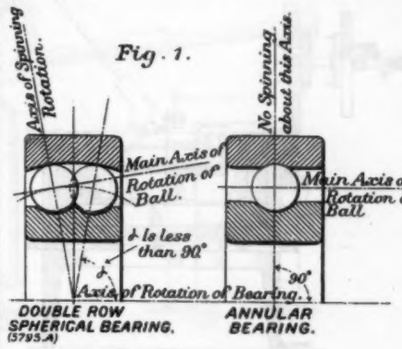


Fig. 1.

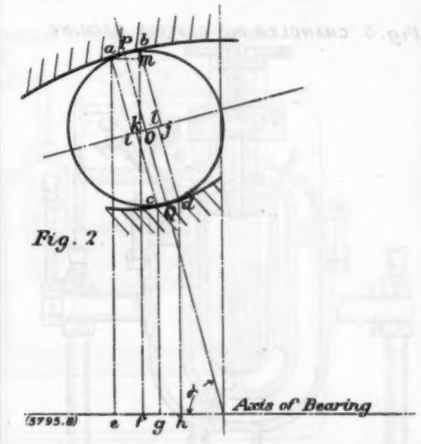


Fig. 2

case of the double-row spherical bearing under the named conditions, whereas he admits that no spinning occurs in the annular type ($\omega_s = 0$). The admission is apparently made unwittingly, and is unfortunately buried among a mass of theoretically-derived figures.

5. The second appeal to practice by your contributor is in paragraph 4, on page 290, where, finding his theories might tend to the disadvantage of the double-row spherical bearing, he takes refuge in practical results without any attempt to justify them.

6. At the present time, when the American journals show that there is a distinct tendency to freak design in ball bearings, the following collection of historical facts deserve particular attention.

(A) The first application of ball bearings on a large scale was made on cycles. The cycle-type bearing suffers from the same disadvantage as the double-row spherical bearing, viz., that the line joining the points of contact on the ball is not at right angles to the spindle. The loads dealt with are light, and satisfactory results are obtained, but the bearing has to be made adjustable to deal with the obvious wear.

(B) The introduction of the automobile led to the trial of cycle-type bearings for heavier loads. They were a complete failure.

(C) This led Professor Stribeck, at the instigation of a large Continental industrial concern, to investigate the principles underlying the correct design of ball-journal bearings. These investigations laid the foundation of the modern ball-bearing industry. Professor Stribeck first enunciated the fundamental principle deduced in paragraph 3.

(D) Modern ball-bearing practice was founded on this principle, and bearings so designed withstood the heavy loads to which they were subjected without any necessity for adjustment. Annular bearings, carrying loads within their capacity and protected from foreign matter, will not show any measurable radial wear even after long periods of running.

(E) This fundamental principle appears to be falling into disregard. If it does, the miserable failures of the cycle-type bearing under heavy loads will be repeated, and the ball bearing industry will be brought into disrepute at a time when every aid to efficiency is required.

In my considered opinion, the greater degree of success which the double-row spherical bearing has had over the cycle-type is entirely due to the fact that the line joining the points of contact on the ball more nearly approaches 90 deg. in the former than in the latter. The highest results can only be attained when the limit of 90 deg. is reached, *i.e.*, in the annular bearing.

This letter has purposely been written in a form such as to make it easily comprehensible, and as the facts contained herein have been arrived at during many years' ball-bearing practice, I hope you will be able to publish them.

I am, Sir, yours faithfully,
W. E. BAKER, B.Eng.,
Associate in Engineering, Sheffield University.
Sometime Ball-Bearing Consultant to the United Motor Industries, Limited.
Lately, Staff-Captain (Technical), Tank Corps.
11, Thornsett-road, Sharrow, Sheffield,
March 10, 1919.

THE BREAKDOWN OF THE ELECTRICALLY PROPELLED BATTLESHIP "NEW MEXICO."

TO THE EDITOR OF ENGINEERING.

SIR,—Much interest has been recently taken in the news which was published in the daily papers, to the effect that the new American electrical battleship had broken down whilst escorting President Wilson across the Atlantic on his return to the United States from France. In order to stop certain reports which have come to my knowledge to the effect that some defect had taken place with the electrical transmission machinery on board that interesting vessel, I shall esteem it a favour if you will give publicity to the news which I have just received, as to what actually has taken place.

It is true that a breakdown did occur; it was caused by one of the two steam turbine prime movers "stripping" the "port" side one, but the New Mexico was never in any danger from this trouble, which is common to all steam turbines. She was able to proceed with her "starboard" side turbine generator at work, and at a speed of 15 knots, and this in extreme heavy weather, so much so that the accompanying destroyers also had to slow down and fall out of the escort.

No apprehension for the New Mexico's safety was ever entertained by American naval officers, who state that the accident was not an unusual one, which is quite obvious to those who have had practical experience in the operation of high-power steam turbines, even ashore. The statement that the electrical machinery had given trouble is absolutely without foundation, no trouble has been experienced, and the greatest enthusiasm is still maintained.

The fact that the New Mexico was able to proceed with all four propellers running at the speed of 15 knots is evidence of the great elasticity and efficiency of the lay-out of plant and the accident can be looked on as a test which has come out most successful, compared with the havoc which would have probably been the result of half the turbine machinery going wrong in the case of an ordinary steam turbine propelled vessel.

Yours faithfully,
WILLIAM P. DURTNALL,
M.I.Mar.E., M.I.Loco.E.,
Inventor and Patentee of the "Paragon" Electrical Ship-Propulsion System.
23, Bessborough-street, Westminster, London, S.W.,
March 15, 1919.

SITUATIONS VACANT.

TO THE EDITOR OF ENGINEERING.

SIR,—I am glad to see the question raised by "G. E. R." on the above subject, appearing on page 339 of your last week's issue, and I fully endorse his statements as to the firm's methods of advertising, &c., in the "Situation Vacant" columns, viz., by asking to *state salary required or salary expected*; and what is worse, that is, when firms advertise what salary they are willing to pay, and then ask to *state salary expected*; and, as "G. E. R." puts it, and rightly so, it resolves itself by the firms accepting the cheapest, regardless of experience—good, bad or indifferent.

There is another question, what chance has an applicant got to quote his salary, not knowing the firm who are advertising, or the class of work carried out by them, or the class of work the applicant may be called upon to do; there are many good men who refrain from answering such advertisements, and in these cases the firms are not obtaining answers to their advertisements from the best men that would avail themselves of a genuine advertisement.

In my opinion, firms would be better served by stating the salaries that they are willing to give, also if they published the name of their firms, or names, rather than resort to Box numbers, &c.

Yours truly,
March 17, 1919. "OPENNESS."

THE RECONSTRUCTION OF BELGIUM.—We are informed that the Economical Council of the Belgian Government have transferred their 110, Cannon-street offices to the following address: Office des Questions Economiques, Ministère des Affaires Economiques, Rue de la Loi, Brussels.

DIE CASTINGS AND THEIR APPLICATION TO THE WAR PROGRAMME.*

By CHARLES PACK,† Brooklyn, N.Y.

DIE castings may be defined as metal castings made by forcing molten metal, under pressure, into a metallic mould or die. It is necessary to keep this definition in mind to avoid confusing this process with other permanent mould-casting processes. The fundamental principles of the process have been known and practised many years. The simplest application is embodied in the modern linotype machine in which molten metal (usually tin-lead alloy) is forced under pressure into a metallic mould. The pressure is derived from a piston and cylinder immersed in the molten metal. Progress in the art of die casting may conveniently be divided into three groups: Machine for imparting pressure to the metal, material for the die or mould, casting alloys.

Casting Machines.—The problem of delivering molten metal under pressure into a die is comparatively simple, when dealing with low fusing-point alloys, as the alloys of lead and tin, but it is much more complicated when dealing with metals of higher fusing points, such as the alloys of zinc, aluminium, and copper. Although the art of die casting is comparative new and, to a large extent, unknown, the records of the Patent Office are replete with patents on the subject.

Fig. 1. UNDERWOOD DIE-CASTING MACHINE

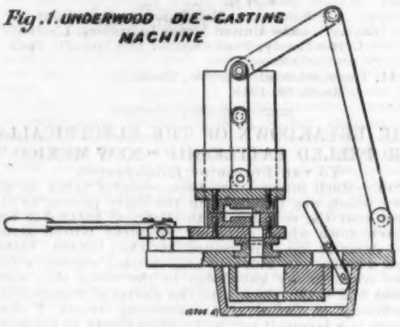


Fig. 4. ANOTHER TYPE OF COMPRESSED-AIR MACHINE.

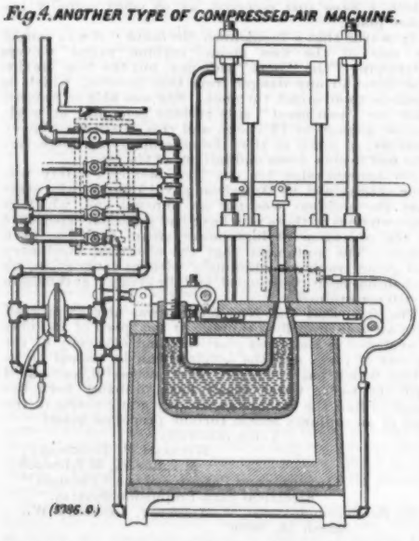


Fig. 1 shows the Underwood machine patented in 1902; this is probably one of the first machines designed for the production of commercial die castings. The relation of this machine to the linotype casting machine is clearly apparent. A cylinder and piston are immersed in the molten metal, the application of power to this piston forcing the molten metal, under pressure, into the mould or die. The Doehler machine, Fig. 2, patented in 1907, is based on the same general principles. This machine is used to a large extent at the present time, throughout the United States, for the production of zinc, tin and lead alloy die castings.

In the machine shown in Fig. 3, patented by Doehler in 1910, compressed air is used for forcing the metal into the die. In Fig. 4 is shown another of this type of machine. Here compressed air is applied to the surface of the molten metal to force it into the die.

In a machine patented by Chandler in 1914, shown in Fig. 5, the principle of the internal-combustion engine is applied for exerting pressure on the molten metal. A charge of gasoline vapour and air is injected into the melting chamber, the explosion of which forces the metal into the die. The writer has never heard of this machine being used on a commercial basis, but it is mentioned to show the various means suggested for forcing molten metal into a die.

Methods Used to avoid Blowholes.—The fact that die castings are made under pressure would suggest, on first thought, dense and homogeneous castings; this impression, however, is not in accord with actual practice. On fracture, the pressure die casting will be found to consist of a dense closely-grained outer stratum and a porous inner stratum. Blowholes of varying size may be expected in the centre of the die casting, particularly through heavy sections. Many machines have been designed with the primary object of overcoming this difficulty and producing solid die castings.

Fig. 6 shows an air-operated die-casting machine with the die enclosed in a vacuum chamber. The inventor evidently assumed that the only cause for blowholes in the casting was the presence of air in the die. In Fig. 7 is shown another die-casting machine in which the vacuum principle is applied; here the vacuum is applied directly to the die.

Fig. 2. EARLY TYPE OF DOEHLER MACHINE

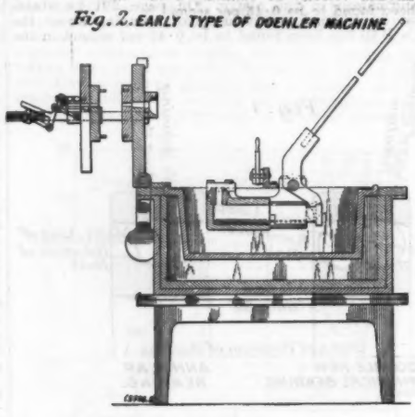
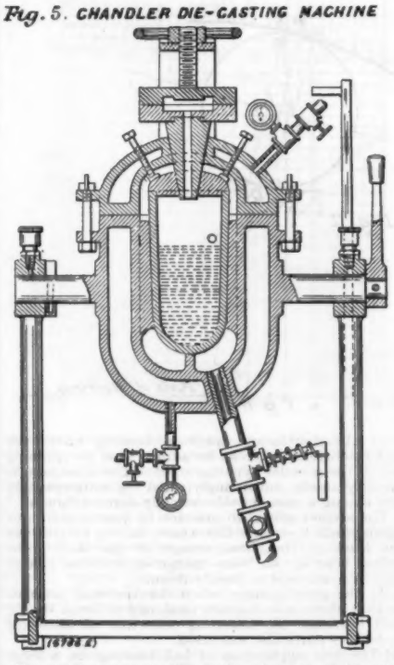


Fig. 5. CHANDLER DIE-CASTING MACHINE



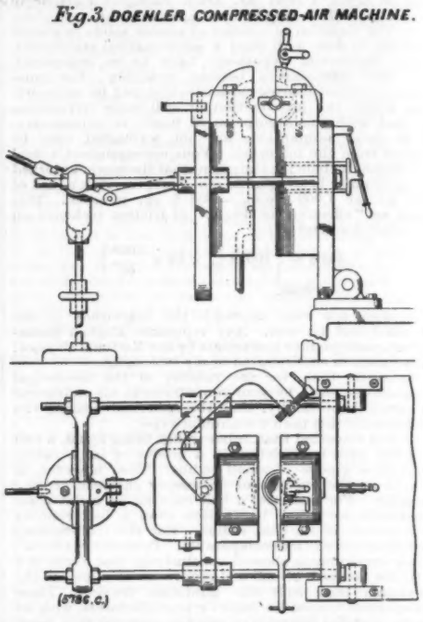
The production of die castings free from blowholes has been the most serious problem confronting die-casting manufacturers. At various times it has been stated that processes capable of producing solid and homogeneous die castings have been developed. If all blowholes in die castings were caused by air coming in contact with metal, the vacuum process would deserve consideration. That the presence of blowholes in some die castings are due to other and more serious causes, the writer will endeavour to prove.

In Fig. 8 is shown a cross-section of a casting that can be gated at A or B; in the best foundry practice the gate A would probably be used. The first metal that goes into the die will chill around the inner walls and take the form shown in the shaded portion. The gate may then become chilled before the inner portion has been filled; this will cause blowholes that no vacuum will eliminate. A similar effect will be produced if the metal was too cold at the time of casting. The writer has produced castings having only an outer shell, similar to that shown in Fig. 8, by limiting the amount of metal injected into the die to a quantity less than that required to make the casting. A similar result may be obtained by running the metal so cold that it will chill the thinner sections of the casting before the heavier sections are completely filled. Lack of pressure will produce the same result.

Blowholes in die castings may also be caused by the phenomenon that we sometimes call "piping." Makers of rolling-mill ingots have often been confronted with this problem. In Fig. 9 is shown cross-section of another casting gated at A. The metal flowing into the die at A will fill the entire mould cavity, assuming all casting conditions to be ideal, but the metal in the thin section adjoining A will chill before the heavier section, so that, the chilling being from the outside, a shrinkage hole will be left in the centre. Here, again, no advantage can be gained by the use of the vacuum system.

Dies.—In the manufacture of die castings from zinc, tin and lead alloys, dies made from low-carbon machine steel last almost indefinitely and answer every purpose. In the first attempts to die-cast aluminium, the problem of obtaining a suitable die material presented serious difficulties, which were described by the writer in a paper read before the American Institute of Metals in 1915. This problem, however, has been solved by the use of various alloy steels making possible the commercial die casting of aluminium and its alloys, which constitute the greater part of the die-casting industry of to-day. The proper gating and venting of these dies are problems that arise daily and on the solution of these problems depends the success or failure of the process.

Fig. 3. DOEHLER COMPRESSED-AIR MACHINE.



Alloys.—In a paper read before the American Institute of Metals in 1914, the writer described the various types of zinc, tin and lead alloys used in the die-casting process. The application of these alloys and their limitations were also pointed out. At that time the die casting of aluminium and its alloys was barely beyond the experimental stage. During the past four years, the most important advance in the art of die casting has been made in the perfection of the process for die-casting aluminium and its alloys. The importance of this achievement as an aid to winning the war is best demonstrated by the fact that at least 95 per cent. of the die-cast parts used directly or indirectly as materials of war were made from an aluminium-base alloy. Of these castings, only a very small percentage could have been produced successfully in 1914.

Investigations of the casting properties of metals and alloys in the past have been generally limited to sand castings; few data are available as to the casting properties of metals or alloys in metallic moulds. Just what constitutes a good die-casting alloy is a subject of unusual interest. A few of the important requirements, outside of the usual physical properties demanded of alloys, are:—

Melting-Point.—The successful die-casting machine in every instance is constructed of iron, in one form or another. The melting-point of the alloy must be such that it will melt readily in an iron pot.

Solvent Action.—The solvent action of the alloy on iron must not be too great. Molten aluminium dissolves iron very rapidly and analyses of aluminium die castings on the market will show an iron content of from 1 per cent. to 3 per cent., due to the solvent action. Fortunately there is no serious objection to the presence of iron in aluminium casting alloys. Should the aluminium absorb much above 3 per cent. iron, the melting point becomes too high and the alloy becomes viscous and unsuitable for making castings.

Elongation.—The elongation of the metal is of vital importance in determining the die-casting properties of an alloy. Not only is it desirable to know the elongation of the alloy when cold, but it is of greater importance to determine the elongation at various temperatures ranging from the melting-point of the alloy down to

* Paper read before the American Institute of Mining Engineers, February, 1919.

† Chief Chemist, Doehler Die Casting Company.

normal temperature. The reason for this becomes apparent when the physical phenomena of the die-casting process are considered. Let us assume that a ring, 12 in. (30·48 cm.) in diameter is to be die-cast in a metallic mould around a metallic core. As the molten metal strikes the mould it solidifies. Here a change of state occurs that is accompanied by a reduction in volume, commonly termed shinkage. Unlike a sand core, the metallic core is not compressible, and retains its original size and form so that the shrinkage of the metal is converted into a stretching action on the solidified casting. If the elongation of the alloy at that temperature is not high enough to withstand this stress the casting will crack. In the usual die-casting practice it is not practical to remove the casting from the die at the solidification temperature of the alloy. For example, the solidification temperature of the aluminium-copper alloys used in the die-casting process is approximately 1,150 deg. F. (621 deg. C.). It has not been found

Fig. 6. MACHINE WITH DIE ENCLOSED IN VACUUM CHAMBER

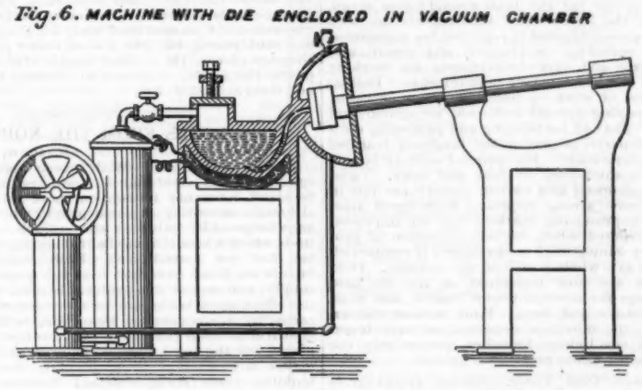
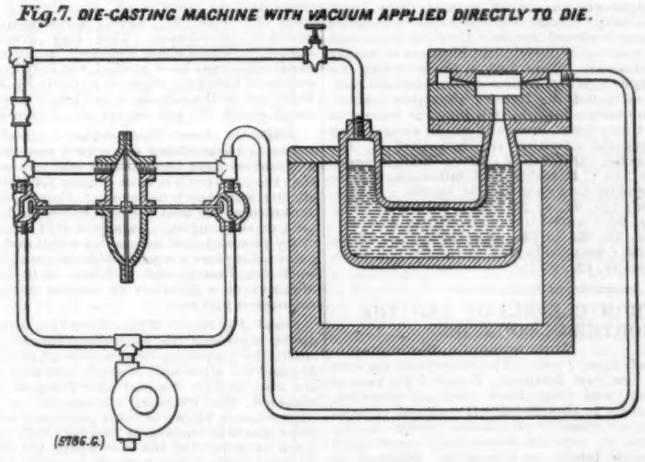


Fig. 7. DIE-CASTING MACHINE WITH VACUUM APPLIED DIRECTLY TO DIE.



practical to run the casting dies above a temperature of 300 deg. F. (260 deg. C.), which means that the castings are withdrawn from the dies at that temperature. It follows that the casting is subjected to another stretching stress after the casting has solidified, due to the contraction in volume that must occur when a casting is cooled from a temperature of 1,150 deg. F. to 500 deg. F.

The writer has been unable to find any reliable method for determining quantitatively the elongation of alloys at various temperatures. Many methods have been suggested but they have proved of doubtful value. The simplest way is to use the old "try-and-see" method. To test the alloy, a casting is made in a die having a comparatively large core and thin wall. If the alloy can stand the casting stress, a perfect casting will be obtained, otherwise the casting will show bad cracks. Only a comparative result is obtained, but for everyday control it answers the purpose. However, a simple and reliable method for determining quantitatively the elongation of metals and alloys at various temperatures would prove of enormous value to all metallurgists engaged in the various phases of metal-casting research.

It is interesting to note that the elongation of a metal or alloy at normal temperatures is no indication as to the properties of that metal or alloy at higher temperatures. The writer has found many cases where an alloy showing little or no elongation at normal temperatures shows a high elongation at higher temperatures. The alloys of aluminium and copper may serve to illustrate this point. It is well known that the addition of copper to aluminium reduces the elongation of the aluminium alloy. An aluminium alloy containing 12 per cent. copper will show less elongation than an alloy containing only 6 per cent. copper when tested at normal temperature. Nevertheless, the 12 per cent. copper alloy has a greater elongation at higher temperatures than the 6 per cent. alloy, and consequently the 12 per cent. alloy is better able to withstand the casting stresses to which it is subjected in the die-casting process.

In the early days of the die-casting industry, alloys were compounded indiscriminately, and little or no consideration was given to the metallurgical principles involved. The manufacturer in many instances knew much more about machinery than about metals. The result was that there were put on the market die castings made from alloys that deteriorated rapidly and created a prejudice among engineers against the use of these castings. That this prejudice was in part justified must be admitted; nevertheless, the modern die-casting plant is equipped with physical and chemical testing laboratories and the die-casting practice of to-day bears no relation to that of five years ago.

Die Castings Made for War Purposes.—Die castings

Fig. 8. CROSS-SECTION OF CASTING WITH TWO GATING POSITIONS.

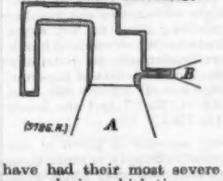
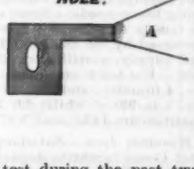


Fig. 9. DIE CASTING CONTAINING SHRINKAGE HOLE.



have had their most severe test during the past two years, during which time most of the die castings manufactured were used directly, or indirectly, in the Government's war programme. Here is a partial list of the application of die castings for this purpose:—

Gas masks, breather tubes and other metal parts.

Lewis machine guns, 100 die-cast parts to every gun.

Browning machine guns, four of the most vital parts.

Naval and army binoculars, the entire housing.

Army truck, tank, and airplane die-cast parts include parts of ignition system, carburettor gasoline-regulating devices, steering-wheel accessories, ball-bearing cages bearings, speed indicators, &c.

Pistol, complete signal pistol.

Submersible bombs, some designs contained as many as 10 die-cast parts.

Hand and rifle grenades, every grenade manufactured in this country contained one or more die castings.

Trench mortar shells, plugs die cast.

Airplane drop bombs, one or more die-cast parts.

Surgical instruments, including hair clippers, respiratory devices, &c.

In many instances, die-cast parts were used where the failure of the part would result in serious loss of life. The fact that not one failure of a die casting has been reported must continue to be a source of deep satisfaction to the modern die-casting manufacturer.

QUEENSLAND COPPER.—There is an abundance of copper in Queensland. It is hard to say where copper cannot be found in more or less large deposits. But, of course, all the copper shows are not worked, and the bulk of the yearly output has been derived from a few favoured mines, which also contain gold and silver in considerable quantities. The celebrated Mont Morgan mine is a proof of this statement, but the extensive district of Cloncurry produces more than half the output of copper of the whole State. Several years ago it was confidently stated that the production of copper would be vastly increased, as would the output of other valuable minerals in the North, by the construction of certain railways. These railways have been built and, in his report on the mining industry, the Under Secretary for Mines lays stress upon the great value of railway communications between the distant mines and the eastern seaports. The vast copper-mining district of Cloncurry has an area equal to that of the whole of Tasmania.

GERMANY AND ALSACE-LORRAINE.—The situation in Alsace-Lorraine from the German point of view is described in the *Frankfurter Zeitung* for January 25. Complaint is made regarding the boycotting of German businesses, involving the sale of these to French people at low prices, and of sharp practice in the matter of money-changing towards the more or less involuntary German emigrants. The food conditions are reported to be satisfactory, frozen meat, rice and colonial produce being abundant, but it is said that the purchasing power of money has diminished. In regard to the Thyssen interests in Lorraine, the same journal expresses the hope that German industry will not be robbed of the fruits of its intensive work in that region. Thyssen and Co. had secured large concessions on both sides of the frontier, so that the minette ore deposits controlled covered an area of 6,000 hectares (14,800 acres). These ores had become valuable after Thomas had introduced a modification of the Bessemer process for iron ores with a high phosphorus content. France has now put under controlled administration the important Thyssen Steel Works at Hagendingen, consisting of smelters, basic steel works and rolling mills, which were started in 1910 with a capital of 1,000,000 marks, and now have smelters and mines valued at 85,610,000 marks and claims amounting to 54,830,000 marks. All these recriminations on the part of Germany are most unbecoming, to say the least. We have in hand accounts of the ruin caused by Germany to works in France and Belgium, and particulars of plant transported whole from those countries and re-erected anew in Germany and Luxemburg. Moreover, German pressmen seem to forget that their diplomats at one time consoled Roumania in regard to the terms imposed upon her by stating that those terms were nothing in comparison to what they intended to demand from France, Belgium and this country.

FACILITIES FOR BRITISH EXPORTS.—In order further to assist exporters to recover their trade in goods of which the export is or has been controlled, and generally to ensure that no openings for trade are lost to British exporters owing to ignorance of existing export facilities, the Department of Overseas Trade in concert with the War Trade Department, has made arrangements for bringing to the notice of exporters through the medium of the Press, trade journals, Chambers of Commerce and trade organisations, and by special notes direct to firms on the "Special Register," of the Department, information regarding changes affecting control over exports. Firms not already on the special register who desire to receive such information direct from the department may apply for admission to the special register to the Comptroller-General, Department of Overseas Trade (Development and Intelligence), 73, Basinghall-street, E.C. 2. The annual fee for admission to the special register is 2*l.* 2*s.*, which includes the supply of *The Board of Trade Journal*. It is understood that owing to the necessary formalities and consequent delay in connection with the obtaining of export licences, exporters find themselves at a disadvantage when dealing with orders requiring immediate acceptance. The department will, therefore, on request, undertake to ascertain from the War Trade Department, and reply by telegram or telephone at the earliest possible moment, whether licences will or will not be granted for such orders. In the event of an applicant being promised a licence he will be enabled to deal with the order straight away with the knowledge that upon application being made formally to the War Trade Department the licence will be granted. Inquiries should be by telegram rather than by telephone and should be addressed to "Orders, C/o Advantage, Stock, London." They should give, in addition, the name and postal or telegraphic address of the applicant, the quantity, value and description of the goods comprised in the order and the name and address of the ultimate consignee if the goods are destined for a neutral country. In the case of orders from allied or British territory or from territory in the occupation of troops of the Associated Governments, the consignee need not be stated; the country of destination will, of course need to be given. A reply of 24 words (1*s.* 6*d.*) must also be prepaid. Applicants are requested in their own interest to confine their inquiries to orders needing a very urgent decision, since the fewer the inquiries the more promptly can answers be given.

THE DIVISIONAL ENGINEERS OF THE ROYAL NAVAL DIVISION.

THE Royal Naval Division was composed originally of the men who came forward from motives of patriotism and enthusiasm. In September, 1914, the Army recruiting machinery had completely broken down, the formation of special battalions was discouraged, the Royal Engineers, the Royal Engineers (Territorial) Electrical Engineers, and other regiments, were declared to be "full" with waiting lists of several hundreds. The creation of the Divisional Engineers of the Royal Naval Division opened a door for technical men, and it appeared at that time their experience in all kinds of engineering would be appreciated and utilised. It is true that if there had been less enthusiasm, and if they had waited, most of these men would have done better for themselves.

Arrangements were at once made by the Institution of Electrical Engineers, assisted by the Institutions of Civil and of Mechanical Engineers, to recruit this unit, and the body of men sent to camp in a few days was remarkable no less for its technical ability than for its eagerness to enlist. As soon as they sailed for the Mediterranean the parent Institutions necessarily lost touch with them.

A committee of the Institution of Electrical Engineers has been appointed to make inquiries about the subsequent history of the Divisional Engineers, and has found that during the Gallipoli campaign it was employed in such work as digging wells and building a jetty—it dwindled owing to casualties, transfers and promotions, and as there was no precedent for the Royal Naval Division, and its Divisional Engineers, there was no organisation to carry on the original formation, and no source from which similar men could be drawn. The unit had become so small by January, 1917, that no other course was possible but to absorb it into the Royal Engineers.

One of the terms of the enlistment was that the Divisional Engineers would have the same standing as Royal Engineers. There was, therefore, no serious hardship in the absorption, except as it affected seniority, &c., though, owing to the *esprit de corps* which had quickly developed, it was greatly to be regretted. Seniority was lost owing to the change; the men were regarded as having joined the army at the date of transfer to the Royal Engineers, their previous services of more than two years being ignored. Seniority was restored for the officers, but possibly this has not been considered with regard to further promotion.

The employment of skilled men on unskilled work has been very common during the war, not only in the Army, but in civil official work. Every man in the unit enlisted as a sapper. The officers as well as the men were employed on unskilled work. It is true that the original contract under which they joined for three years or for the duration of the war, whichever were the shorter, was broken, and the conditions under which the men joined were not retained. But this is done under an Act which applied to men in all regiments.

That their engineering experience was but little appreciated by the military authorities is a matter beyond any control or influence that the engineering Institutions could exercise. The value of that experience and the enthusiasm of those who offered themselves is known to nobody better than to those members of the Institutions who took part in the recruiting; and nobody can more deeply regret the waste of this fine unit than those who are proud to have been permitted to help to form it.

The Institution of Electrical Engineers has records of the following who enlisted in the Royal Naval Division:—

Officers	60
N.C.Os.	19
Sappers	24
Killed	9
Discharged	11
	123

The total number of members of the Institution of Electrical Engineers who have joined the Services is about 2,000. Circulars have been sent out by the Electrical Appointments Board to every known case, and about 600 replies have been received.

The early date of voluntary enlistment, and consequently their long service, to say nothing of the disappointments which have been experienced, should weigh with the Institutions and their members in endeavouring to find appointments for men who joined as Divisional Engineers of the Royal Naval Division.

MANGANESE IN THE TRANSVAAL.—According to *The South African Mining Review* an important discovery of manganese ore has been made near Pretoria. The lode has a width of 4 ft., and has been traced so far for 300 yards, outcropping. It contains 80 per cent. of manganese.

AMERICAN INSTITUTE OF MINING AND METALLURGICAL INSTITUTE.—The name of the American Institute of Mining Engineers has been changed to the American Institute of Mining and Metallurgical Institute, says the Institute's Bulletin for the present month, No. 147. The same Bulletin states that the committee appointed by Mr. W. R. Ingalls, president of the Mining and Metallurgical Society of America, to nominate candidates for the annual gold medal of the society, consisted of Mr. E. G. Spilsbury, Mr. J. E. Johnson, Junr., and Mr. Bradley Stoughton. This committee recommended Mr. Schneider, Creusot and other subsidiary works in France, for achievements in ferrous metallurgy, which recommendation was approved by the society.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The uncertainty of the outlook is well illustrated in opinions expressed by two leading manufacturers this week. One opinion is that a ready market exists for the whole of the South Yorkshire output and that no difficulty is likely to be experienced in the future in maintaining activity in all branches; and the other that pressing requirements will ensure temporary prosperity, but that a period of bad trade will follow unless prices can be favourably reduced to attract export trade. That a healthy undertone exists, however, is proved by the big current expenditure on electrical plant and machinery, and on constructional steel for works extensions and equipment. The iron market is dull; complaints from users as to inability to secure prompt deliveries, are the rule rather than the exception. Slightly increased activity is shown in the market for iron and steel scrap. Guaranteed qualities of the latter are in strong demand, and there is also a ready sale for the best wrought-iron scrap. On the whole, the heavy steel departments are well employed. A strong demand is reported for manganese trackwork for tramway construction and repair, and the railway axle and tyre departments are working under pressure to meet contract requirements. Rolling mills have a lot of work on hand for these sections, and are also paying special attention to agricultural requirements. The call for farming and gardening tools and implement parts, is one of the brightest features of South Yorkshire trade. Exceptional activity is also shown in the manufacture of files and saws. Twist drills of the high-speed and carbon variety are not in anything like such strong request. High-speed steel is a flat and unpromising market, but an improved inquiry is anticipated when the reconstruction of production to meet commercial requirements is completed. Unemployment as a whole is still on the increase. Over 20,000 workers are now registered at the Sheffield Labour Exchange for unemployment benefit, but most of these are women and boys. Many women thrown out of work in the munition departments have found employment in the lighter branches, particularly the tool-making trades, where pressure is greatest.

South Yorkshire Coal Trade.—Special attention is being paid to building up reserves for emergency purposes, and this is accentuating the scarcity in all classes of fuel Best steam hards are in strong request from home consumers. Railway companies are pressing for supplies to improve their depleted stocks. Cobbles, nuts and slacks are all in active demand, but business is mostly confined to contractors, whose wagons are removing the bulk of the output. When their requirements are met, there is practically nothing left for the open market. The demand for house coals is still much in excess of the supply, and merchants generally are in arrears with orders. The general situation is aggravated by the scarcity of wagons. Quotations:—Best branch hand-picked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—The Cleveland pig-iron trade presents few new features. Foundry pig-iron is still very scarce, and forge kind continues plentiful. At present business is almost entirely confined to sales to meet immediate home requirements, traders having little inclination to commit themselves ahead with outlook as regards labour as it now is. Demand on behalf of neutral countries is still very heavy, but what they chiefly want is foundry iron, and there is practically none of that quality to spare for shipment abroad, the supply, in fact, falling considerably short of satisfying home needs. Some slight increase in the number of trucks is reported, but nothing like the 850 extra promised by the Board of Trade have yet come to hand, and supply is still altogether inadequate to distribute iron. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry, and No. 4 forge are all quoted 95*s.*, and No. 1 is 99*s.*; whilst for export, No. 3 and the lower qualities are 145*s.*, and No. 1 is 150*s.*

Hematite Iron.—Satisfactory account is given of the East Coast hematite department. Supply is more than sufficient for home requirements, and may shortly be increased, a rumour being current that two or three furnaces now manufacturing other descriptions of iron are to be transferred to the production of hematite. Under these circumstances it is not surprising to find exporters more pressing than ever in their effort to obtain permits to ship abroad. The authorities, however, appear still disinclined to issue export licences, and consequently foreign trade is on a very limited scale. Mixed Nos. are 122*s.* 6*d.* for home use, and 172*s.* 6*d.* for export.

Foreign Ore.—As yet there is little new business passing in foreign ore after the discontinuance of control of shipping, nor do many steamers appear to have been fixed in the open market, but renewal of activity is confidently anticipated, so soon as sellers and consumers agree on a basis for future transactions.

Coke.—Coke keeps very strong, though decidedly less scarce than it has been. Supplies to the blast furnaces are now stated to be regular and adequate, but stocks are low, and consumers are still pressing for larger deliveries. Medium furnace coke is 33*s.* at the ovens, and quality low in phosphorus 35*s.* 6*d.* at the ovens.

Manufactured Iron and Steel.—Great firmness still characterises the finished iron and steel industries notwithstanding threatened American competition, and inquiries on both home and foreign account were reported numerous and substantial. At the same time report of offer of American steel in this country, at prices below that of home product, is viewed with apprehension. Continued difficulty of transport, owing to the truck shortage, and consequent congestion at the works, has been responsible for stopping steel mills and furnaces involving considerable reduction of output. It is hoped, however, that congestion in the stock yards will be speedily relieved. Quotations are quite firm. To home customers, common iron bars are 17*l.* 15*s.*; steel ship, bridge and tank plates, 14*l.*; steel boiler plates, 15*l.*; chequer plates, 15*l.* 10*s.*; steel angles, 13*l.* 12*s.* 6*d.*; steel joists, 13*l.* 12*s.* 6*d.*; steel billets, and blooms, 12*l.* 5*s.* to 12*l.* 15*s.*; and steel rails, 13*l.* 10*s.*; whilst for export the following are among the principal market quotations: Common iron bars, 20*l.*; steel ship, bridge and tank plates, 16*l.* 10*s.*; steel boiler plates, 17*l.* 10*s.*; chequer plates, 18*l.*; steel angles, 16*l.* 2*s.* 6*d.*; steel joists, 16*l.* 2*s.* 6*d.*; billets and blooms, 13*l.* 10*s.* to 15*l.* and steel rails, 15*l.* 10*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—With every rolling mill fully employed, the steel-making industry in the West of Scotland continues to run on most satisfactory lines, although, according to some people who consider their knowledge alike valuable and reliable, the volume of trade which was anticipated at the signing of the armistice has not yet materialised. Both manufacturers and buyers are much exercised over the question of the coal supply, and unless this problem is settled very speedily the effect upon trade will be more serious than anyone cares to contemplate. Meantime, while sufficiently plentiful to keep the works busy, orders are only being placed for the most immediate necessities, and no one makes any attempt to accumulate stock. The shipbuilding yards make constant demand for deliveries of ship and boiler plates, but sections are not at the moment so greatly in request. Export shows little disposition to come away, the high prices and heavy costs of freight, &c., having a restraining influence on would-be purchasers. This may give America the chance for which she is watching, as, even already, some small shipments have arrived, not only here, but in other countries formerly supplied entirely by British makers. Prices are well maintained and likely to rise, steel plates round about 20*l.* per ton are not uncommon.

Malleable Iron Trade.—The malleable iron trade seems to have settled down to a run of good business, and makers have succeeded so well in overtaking arrears that the pressure has been greatly relieved and deliveries effected with much more ease. General engineering and agricultural sections for the home markets absorb the bulk of the output. Export is still weak, but there is every prospect that as soon as a full and proper adjustment takes place a considerable amount of reconstruction work for France and Belgium will be undertaken, inquiries of a satisfactory nature being an everyday occurrence just now.

Scotch Pig-Iron.—While there is a certain amount of doubt regarding the immediate future of the pig-iron trade, the prevailing briskness is all in its favour. The demand for all brands is good, and although shipments are still strictly limited and licences not too easily obtained, the overseas consumers are making their requirements known in most persistent manner. In the home markets business is moving freely, hematite being much in request at the steel works, notwithstanding the almost complete cessation of war work. Prices show no change.

Shipbuilding at Port Glasgow.—Messrs. Lithgows, Limited, Kingston Shipbuilding Yard, Port Glasgow have just placed two new vessels in the water—one a standard cargo steamer, 356 ft. in length, with a deadweight carrying capacity of about 8,000 tons; the other, also a cargo carrier, being 500 ft. in length, 7,650 tons gross, and 11,600 tons deadweight carrying capacity. The machinery for the two vessels is being supplied, respectively, by Messrs. Rankin and Blackmore, Greenock and Messrs. Dunsmuir and Jackson, Glasgow.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Irregular strikes continue to take place in the South Wales coalfield, and this naturally has a prejudicial effect upon outputs. A rather curious position is that in connection with the stoppage at Messrs. Guest, Keen and Nettlefolds, Dowlais Collieries where about 6,000 men are now idle. The men stopped work without any notice, and while negotiations were actually taking place for a settlement of the points at issue between the management and the employees. The Coal Controller has been interesting himself in the matter and his representative had two days' interviews with the workmen's representatives. As a result of these interviews an arrangement was made regarding the terms upon which the men should resume work. Strangely enough, however, the colliery company was not consulted at all, and were not given any information as to what were the terms which had been agreed upon between the Coal Controller's representative and the workmen. In these circumstances the company have

refused to allow a resumption of work, and at a meeting of the Disputes Committee of the Joint Coal Board held yesterday, the owners' representatives pointed out that the company could not be expected to accept an agreement to which they were in no ways parties. It is understood that the workmen's representatives are again going to interview the Coal Controller on the subject; but in view of the extraordinary way in which the dispute has been handled, there seems to be no immediate prospect of a settlement. In the mid-Rhondda, too, further irregular stoppages took place yesterday affecting altogether about 10,000 men. On the very day that the men abruptly adopted a down tools policy the points of differences which had arisen were adjusted at the Joint Disputes Committee held at Cardiff. It is not, however, expected that the stoppages of the mid-Rhondda collieries will be prolonged, inasmuch as the miners' leaders from that district disapprove entirely of the action of the men. Naturally a great deal of interest is being taken in the proceedings before the Coal Commission. This, indeed, forms the chief topic of discussion on the local markets, but it is felt that it is futile to speculate with any degree of certainty as to what may be the result. It is, however, felt that the Commission will not be likely to result in the whole of the demands of the miners being granted; this, too, is the view held by some of the most prominent of the miners' leaders themselves. In these circumstances, therefore, the indications point to trouble and a stoppage is more than likely unless there has been a good deal of the game of "bluff" indulged in on the part of the men's representatives. So far as the coal market itself is concerned business has been very slow and difficult. The inland inquiry has been of a very pressing character, and collieries have been very busy supplying the demands of railways and works. The authorities, too, have been very busy, with the result that very little coal has been left for export. Even for allied countries it has been difficult to secure the release of fuel, and for neutrals it was only in isolated cases that shipment was sanctioned. Large coals of all classes were very tight, but the cheaper descriptions of steam and dry smalls continued plentiful and without much inquiry. There is plenty of tonnage at the local docks, and the tipping facilities are not sufficient to cope with the loading requirements. In some cases vessels have been waiting over a fortnight for cargoes.

Newport.—Monmouthshire large steam coals have been difficult to secure for export, owing to the refusal of the authorities to release supplies, and also to the heavy inland inquiry. The docks are full of vessels, and many of these are delayed by the refusal of the authorities to release cargoes. This is especially the case in respect to vessels going to neutral countries. A shortage of engine power on the railways is also aggravating the position, and some collieries find it difficult to keep going owing to a lack of empty wagons. Bunkers qualities and the best classes of small steams are also scarce, but the inferior grades of small steams are plentiful, despite the fact that a percentage of these have to be shipped in nearly all cargoes.

The Boilermakers' Strike.—The strike of boilermakers in the Bristol Channel continues, and has been the result of a rather curious position. On Saturday last the men at a mass meeting decided to present themselves for work on Tuesday morning, on day rates, with a 47-hours' week. The rates were 7*s.* per day for platers, 6*s.* 6*d.* for riveters, and 5*s.* for holders-up, plus the war bonus of 25*s.* 6*d.* a week and 7½ per cent. In accordance with this decision, the men presented themselves for work yesterday morning and were informed by the employers on what conditions they could resume operations. As these conditions were not in accordance with the decision of the boilermakers they refused to restart. The strike, therefore, continues. The men were informed that they could resume work on the new riveters' price list, plus the 10 per cent., and that jobs now in hand that are well advanced, to which the new list could not reasonably be applied, shall be completed on the working conditions on which those jobs were left unfinished (that is, the rates then prevailing). Wherever the new riveters' price list could be applied, it was to be immediately worked to. Any special piece work rate per hundred (rivets) that had been arranged on work in progress (described as jobs in hand well progressed) would have the benefit of the 10 per cent. additional named above added to same until such job was completed, this concession to be without prejudice to the continued negotiations for arranging the new riveters' price list.

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—The council of this Institution have decided to hold a summer meeting at Newcastle-on-Tyne during the early part of July next, the objects being to review the progress made during the war in certain branches of engineering and shipbuilding. Details of the meeting will be issued in due course.

TRADE WITH SOUTH RUSSIA.—Arrangements have been concluded whereby it will be possible for a strictly limited number of business men, desiring to proceed to Constantinople and South Russia, to travel *via* Marseilles and Malta. Business men wishing to avail themselves of these facilities should apply in the first instance to the Russian Section, Department of Overseas Trade, Sunderland House, Curzon-street, Mayfair, W. 1., who will, in approved cases, issue certificates, on production of which Messrs. Thomas Cook and Son have undertaken to make the necessary booking arrangements. The fare will be 20*l.* from Marseilles to Constantinople, plus the ordinary fare to Marseilles, but this will not, of course, include maintenance during any period of detention in Malta. It is understood that a weekly steamship service has been established between Salonica and Odessa, *via* Constantinople.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, March 21, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster. General Meeting. Paper: "Jigs, Tools and Special Machines, with their Relation to the Production of Standardised Parts," by Mr. H. C. Armitage, of Birmingham, Associate Member.

THE MANCHESTER ASSOCIATION OF ENGINEERS.—Saturday evening, March 22, the Annual Meeting of the Association will be held at the Grand Hotel, Manchester. The chair will be taken precisely at 6.30 p.m. After the transaction of the ordinary business of an annual meeting, a paper will be read by Mr. J. Edgar Hurst, on "Impact Testing."

THE BIRMINGHAM METALLURGICAL SOCIETY.—Saturday, March 22, at 6.30 p.m., Joint Meeting with the British Foundrymen's Association at the Technical School, Suffolk-street. Paper by Mr. J. H. Stansbie, B.Sc., upon "The Electric Furnace." Thursday, March 27, at 7.30 p.m., at the Birmingham Chamber of Commerce, New-street, paper by Mr. S. N. Brayshaw, M.I.Mech.E. (Manchester), "The Heat Treatment of Tool Steels."

THE ROYAL SOCIETY OF ARTS.—Monday, March 24, at 4.30 p.m., Cantor Lecture: "Coal and its Conservation," by Mr. William Arthur Bone, D.Sc., Ph.D. F.R.S., Professor of Chemical Technology (Fuel and Refractory Materials), Imperial College of Science and Technology. (Lecture III.) Wednesday, March 26, at 4.30 p.m., Ordinary Meeting: "British Engineering and Hydro-Electric Development. (The Training of Engineers.)" by Mr. Arnold Hartley Gibson, D.Sc., M.I.Mech.E., Professor of Engineering, University College, Dundee. Mr. Alan A. Campbell Swinton, F.R.S., M.Inst.C.E., M.I.E.E., chairman of the Council of the Society, will preside.

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS (INCORPORATED).—Tuesday, March 25, at 6.15 p.m., in the Lecture Theatre of the Literary and Philosophical Society, Westgate-road, Newcastle-on-Tyne, the following paper will be discussed: "Machine Tools," by Sir Alfred Herbert, K.B.E.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, March 25, at 5.30 p.m. Papers to be further discussed: "Electric Welding Developments in Great Britain and the United States of America," by Mr. James Caldwell and Mr. Henry Bailey Sayers; "Experiments on the Application of Electric Welding to Large Structures," by Mr. Westcott Stile Abell, M.Eng., M.Inst.C.E.; "The Application of Electric Welding in Ship Construction and Repairs," by Mr. John Reney Smith.

THE INSTITUTE OF METALS.—Annual General Meeting in the Rooms of the Chemical Society, Burlington House, Piccadilly, W. 1, on Tuesday and Wednesday, March 25 and 26, 1919. The meeting will commence at 4 p.m. on both days. Tuesday, March 25 (afternoon session, 4 p.m. to 6.30 p.m., and evening session, 8 p.m. to 10 p.m.):—Report of the Council on the work of the Institute during the past year. (1) Fourth Report to the Corrosion Research Committee, by Captain G. D. Bengough, D.Sc., M.A., Member, and Mr. O. F. Hudson, D.Sc., Member (London). (2) "The Properties of Some Copper Alloys," by Mr. W. Rosenhain, D.Sc., F.R.S., Vice-President, and Mr. D. Hanson, M.Sc., Member (Teddington). (3) Note: "Metallurgical Information Required by Engineers," by Lieutenant-Colonel C. F. Jenkin, R.A.F., M.A., M.B.E., Member (Oxford). Wednesday, March 26 (afternoon session, 4 p.m. to 6.30 p.m.):—(4) "The Micrography of Aluminium and its Alloys," by Mr. D. Hanson, M.Sc., Member, and Mr. S. L. Archbutt, F.I.C., Member (Teddington) (5) "Effect of Work on Metals and Alloys," by Mr. Owen W. Ellis, M.Sc., Member (London). (6) Note: "The Influence of Cold Rolling upon the Mechanical Properties of Oxygen Free Copper," by Mr. F. Johnson, M.Sc., Member (Birmingham). Wednesday, March 26 (evening session, 8 p.m. to 10 p.m.):—(7) General discussion on the relation of science to the non-ferrous metals industry, opened by Mr. W. Rosenhain, D.Sc., F.R.S., Vice-President, with paper on "Science and Industry in Relation to Non-Ferrous Metals," and followed by (8) Note: "The Relationship between the Laboratory and the Workshop," by Mr. W. R. Barclay, Member (Sheffield), and (9) Note: "The Scope of the Works' Laboratory," by Mr. F. C. A. H. Lantsberry, M.Sc., Member (Birmingham).

THE INSTITUTION OF ELECTRICAL ENGINEERS: SOUTH-MIDLAND CENTRE.—Wednesday, March 26, at 7 p.m., at the University, Edmund-street, Birmingham, when Mr. R. J. Kaula, M.I.E.E., will read his paper entitled "Condensers."

THE INSTITUTION OF MECHANICAL ENGINEERS: MANCHESTER MEETING.—Thursday, March 27, at 7 p.m., a meeting of the Institution of Mechanical Engineers will be held at the Engineer's Club, Manchester, when Mr. H. C. Armitage will read his paper on "Jigs, Tools and Special Machines and the Production of Standardised Parts." The Council of the Institution cordially invite the Members of the Manchester Association of Engineers to be present at this meeting.

THE CONCRETE INSTITUTE.—Thursday, March 27, at 5.30 p.m., in the Lecture Hall at Denison House, 296, Vauxhall Bridge-road, Westminster. Paper by Mr. J. S. E. de Vesian, M.I.Mech.E., on "Ferro-Concrete Ships."

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, March 27, at 6 p.m. (light refreshments at 5.30 p.m.), at the Institution of Civil Engineers, Great George-street, Westminster, S.W. Paper by the late Mr. H. R. Constantine, on "The Co-ordination of Research in Works and Laboratories." (To be read by Mr. J. S. Highfield, Member.)

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, March 28, at 5.30 p.m., a discourse will be delivered by the Right Hon. Sir J. H. A. Macdonald, G.C.B., LL.D., F.R.S., M.I.E.C. The subject will be "The Air Road." Afternoon Lectures, at 3 p.m.: Tuesday, March 25, Professor A. Keith, M.D., LL.D., F.R.S., F.R.C.S., Fullerian Professor of Physiology, Royal Institution, on "British Ethnology—The People of Scotland" (Lecture II). Thursday, March 27, Professor C. H. Lees, D.Sc., F.R.S., on "Fire Cracks and the Forces Producing Them" (Lecture II). Saturday, March 29, Professor Sir J. J. Thomson, O.M., LL.D., D.Sc., Pres.R.S., Professor of Natural Philosophy, Royal Institution, on "Spectrum Analysis and its Application to Atomic Structure" (Lecture IV).

THE GOLD MEDAL OF THE INSTITUTION OF NAVAL ARCHITECTS.—It is announced that the annual gold medal of the Institution of Naval Architects for the past year has been awarded to Mr. A. M. Robb, B.Sc. (associate member) for his paper on "The Shearing Force and Bending Moment acting on the Structure of a Ship," and the premium to Major M. Denny, S.B., C.B.E. (member) for his paper on "The Possibilities of Reinforced Concrete as a Material for Ship Construction."

MICHELL BEARING PATENT.—We are informed that by a judgment recently given by Mr. Justice Sargant, in the High Court of Justice, Chancery Division, the patent No. 875, of 1905, granted to Mr. A. G. M. Michell for improvements in thrust bearings, has been extended for a period of seven years. In his judgment, Mr. Justice Sargant said that the remuneration so far received by the patentee could not be considered adequate, and that in view of the exceptional utility of the patent and the benefits conferred on the public by the invention, he had come to the conclusion that the extension should be granted for the full term of seven years. The extension was, however, subject to undertakings by the inventor to renew existing licences at existing royalties, and, in granting any future licences, to charge royalties and lump sum payments not exceeding twice the amount under Messrs. Harland and Wolff's licence. The merits of this invention, and the principles of lubrication it embodies, are probably well known to most of our readers, it having been illustrated and described in our columns on several occasions. Amongst other interesting facts brought out in evidence given in connection with the above case, it appears that bearings transmitting nearly 10,000,000 h.p. had been or were being, fitted by the British Admiralty, mostly for use in geared turbine installations. In many cases powers were being transmitted that could not be dealt with by the old multi-collar type of thrust block, and, in one installation, as much as 40,000 h.p. is to be transmitted per shaft. Mr. H. T. Newbigin, of 3, St. Nicholas' Buildings, Newcastle-on-Tyne, is agent for the inventor of these bearings.

NAVAL HONOURS.—The following honours have, with the approval of His Majesty the King, been conferred upon naval engineers, among others:—For valuable services rendered in connection with the war: To be an O.B.E. (Military), Engineer-Lieutenant Edward Richards, R.N. For services in action with enemy submarines: To be Companions of the Distinguished Service Order, Engineer-Commander E. C. Green, R.N., and Engineer Lieutenant-Commander R. J. Brown, R.N. To receive the Distinguished Service Medal, Chief Engine-Room Artificer R. P. Nicolas. To receive the Meritorious Service Medal, Chief Engine-Room Artificers F. Collett, R. E. Collingwood, F. G. Deal and H. S. Gregory, and Engine-Room Artificer Rupert Barker. Mentioned in Despatches, Engineer-Commander Edwin Cole, R.N.; Chief Artificer Engineer William Nock, R.N.; Chief Engine-Room Artificers Arthur Deverill, J. P. Perry, E. W. Preece and W. J. Bickle; and Engine-Room Artificers F. A. David and Francis Rayment. For miscellaneous services: To receive the Distinguished Service Medal, Chief Engine-Room Artificer C. F. Wilkins and Engine-Room Artificer T. H. Hodge. Mentioned in Despatches, Engineer Lieutenant-Commander G. H. Turrall, R.N., and Chief Engine-Room Artificers Alex. Cunningham and James Macdonald. For services in the mercantile marine: To receive the Distinguished Service Cross, Chief Engineer E. R. Crafter. Commended for Services, Chief Engineers W. J. Frederick, R. Gifford and H. E. Westhorp. His Majesty the King of Roumania has conferred a Commandership of the Order of the Star of Roumania upon Engineer Vice-Admiral Sir George G. Goodwin, K.C.B., and an Officership of the same Order upon Engineer Lieutenant-Commander G. W. Le Page, D.S.O., R.N. The King of Roumania has conferred upon Engineer-Commander R. D. Morton, R.N., an Officership of the Order of the Crown of Roumania and a Chevaliership of that Order upon Engineer-Lieutenant Frank Kydd, R.N.R., while he has given the "Cross of Military Virtue" of the first class to Chief Engine-Room Artificer P. W. Dewsbury, R.N.R., and Engine-Room Artificers Thomas Atkinson and P. R. Blacklock, and of the third class to Engineman J. T. Williams, R.N.R. The following decorations have been conferred by the President of the French Republic: The Medaille Militaire upon Chief Engine-Room Artificer F. T. Birchall and Chief Engineman James Ewing and Alex. Noble.

THE WAR DEVELOPMENT OF THE TORPEDO-BOAT DESTROYER.

(*For Description, see Page* 362.)

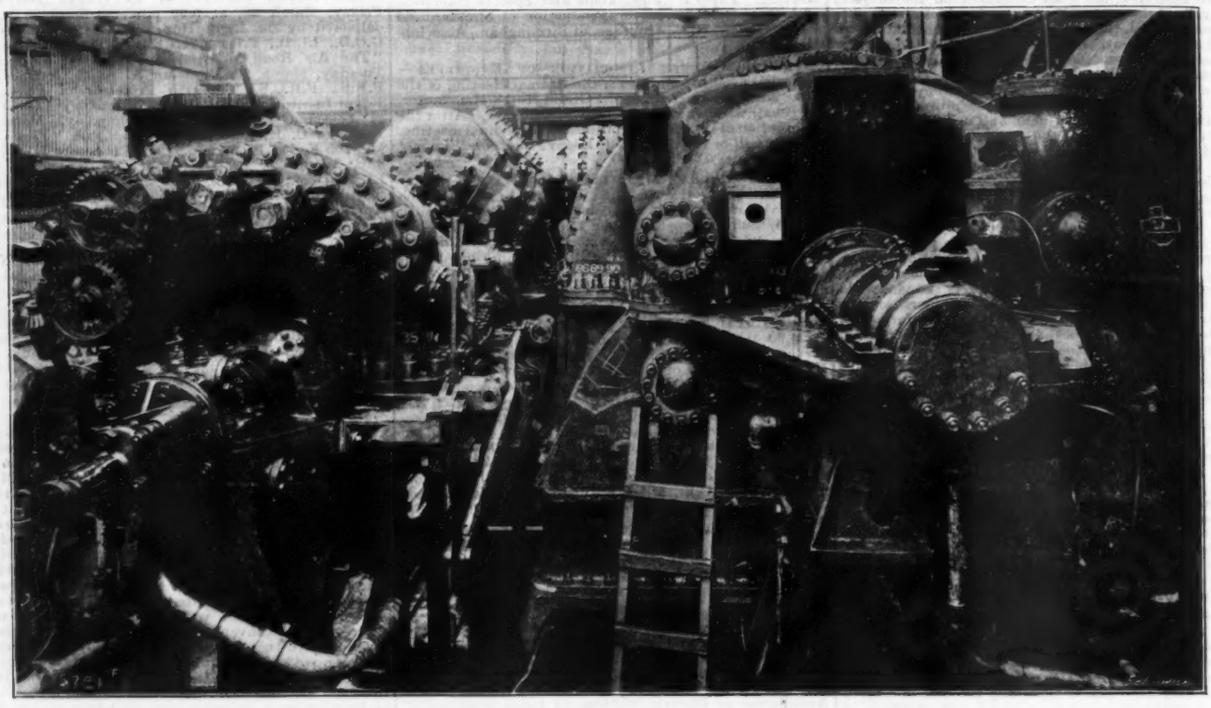


FIG. 10. VIEW OF GEARED TURBINES FOR FLOTILLA LEADER; MESSRS. JOHN I. THORNYCROFT AND CO., LIMITED, SOUTHAMPTON.

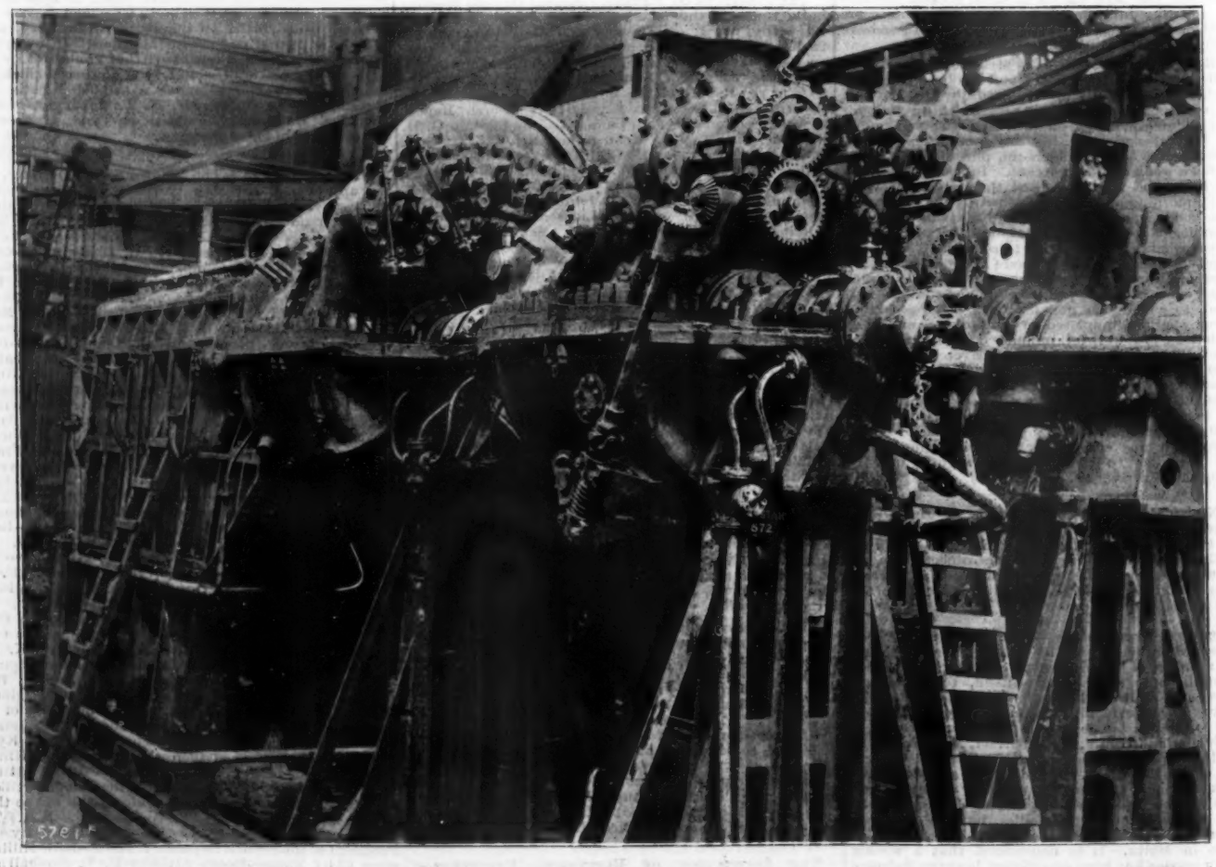
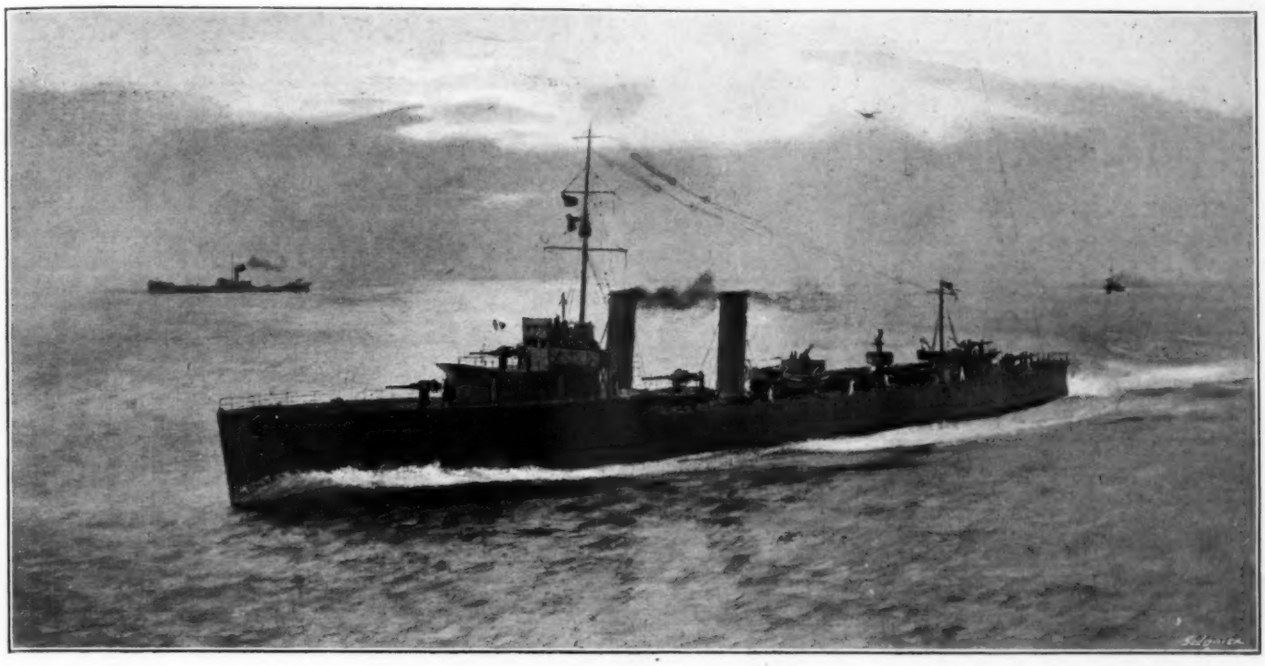


FIG. 11. GEARED TURBINES AND CONDENSERS OF FLOTILLA LEADER.

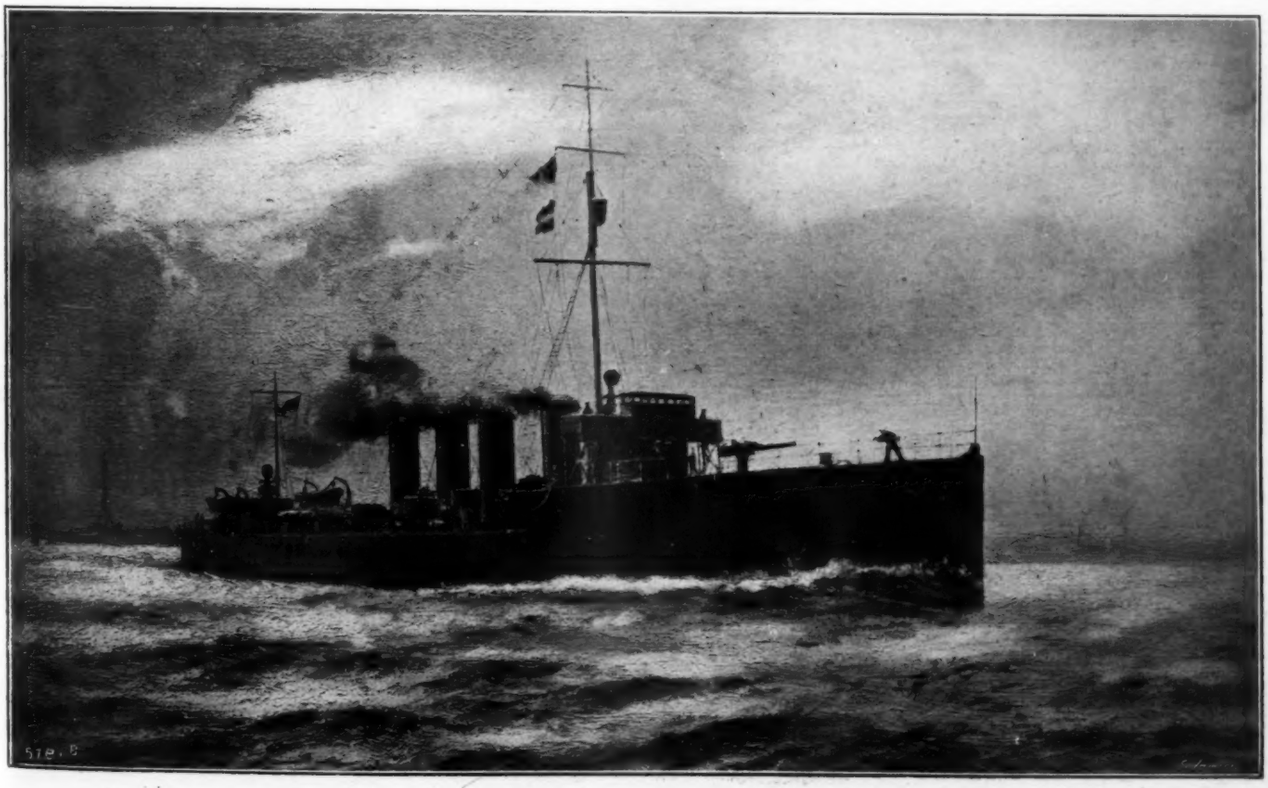
THE WAR DEVELOPMENT OF TORPEDO BOAT DESTROYERS.

(*For Description, see Page* 362.)



[*Copyright, from a painting by* A. J. W. Burgess, R.I.]

Fig. 1. The Flotilla Leader H.M.S. "Scott"; Messrs. Cammell Laird and Co., Limited, Birkenhead.



[*Copyright, from a painting by* A. J. W. Burgess, R.I.]

Fig. 2. H.M.S. Flotilla Leader "Kempenfelt"; Messrs. Cammell Laird and Co., Limited, Birkenhead.

(*To face page* 362.)

THE WAR DEVELOPMENT OF TORPEDO BOAT DESTROYERS.

(*For Description, see Page* 362.)

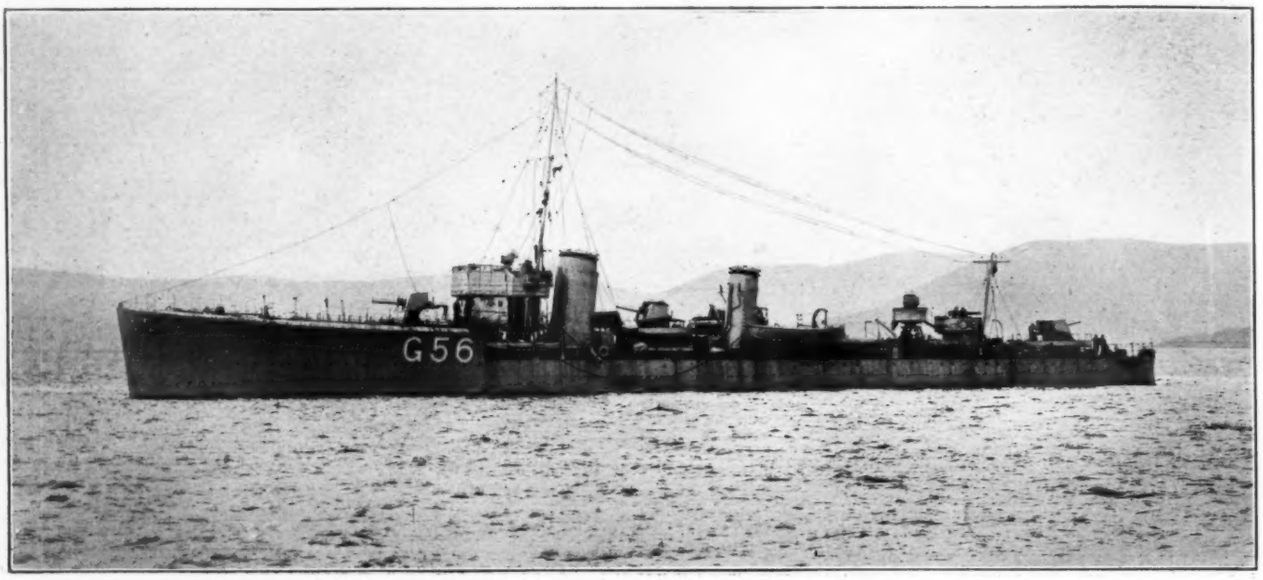


FIG. 3. H.M. TORPEDO BOAT DESTROYER "SABRE"; MESSRS. ALEXANDER STEPHEN AND SON, LIMITED, LINTHOUSE, GLASGOW.

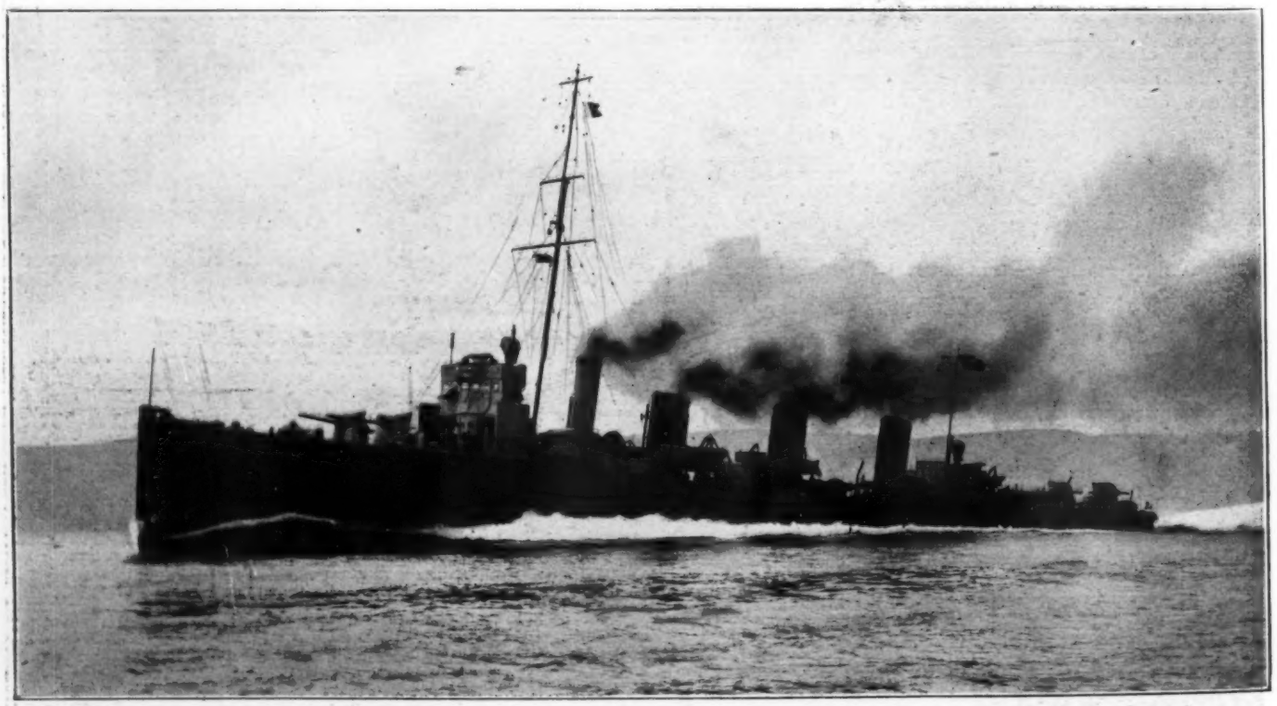


FIG. 4. H.M. FLOTILLA LEADER "BROKE"; MESSRS. J. SAMUEL WHITE AND CO., LIMITED, EAST COWES, ISLE OF WIGHT.

THE WAR DEVELOPMENT OF TORPEDO BOAT DESTROYERS.

(*For Description, see Page* 362.)

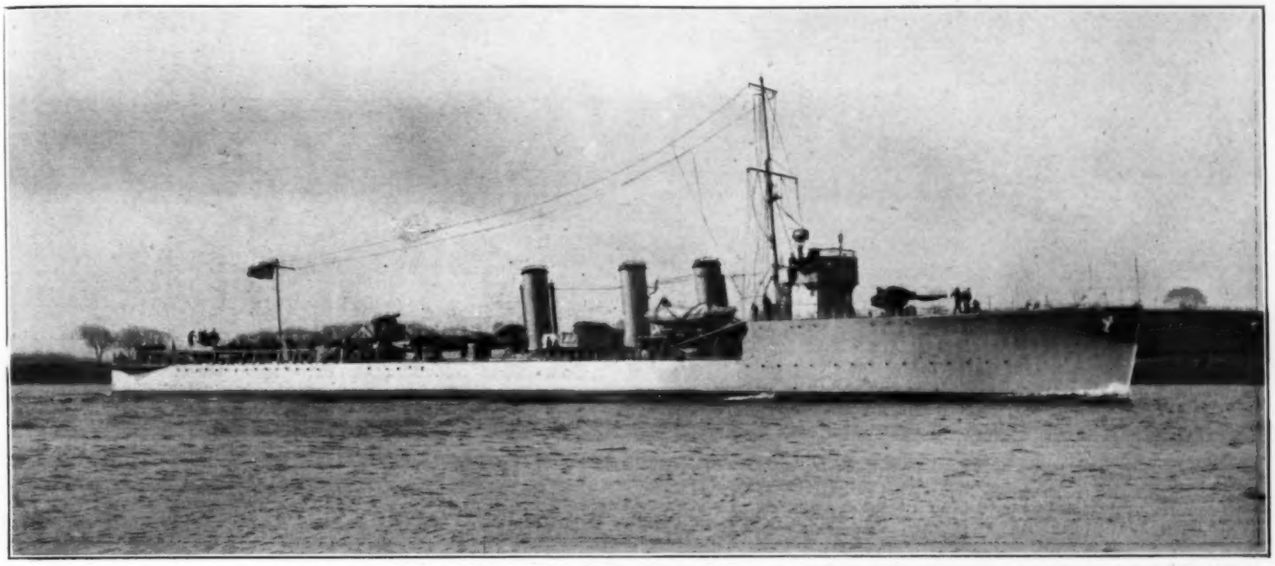


Fig. 5. H.M. Torpedo Boat Destroyer of the "M" Class; Messrs. John Brown and Co., Limited, Clydebank.

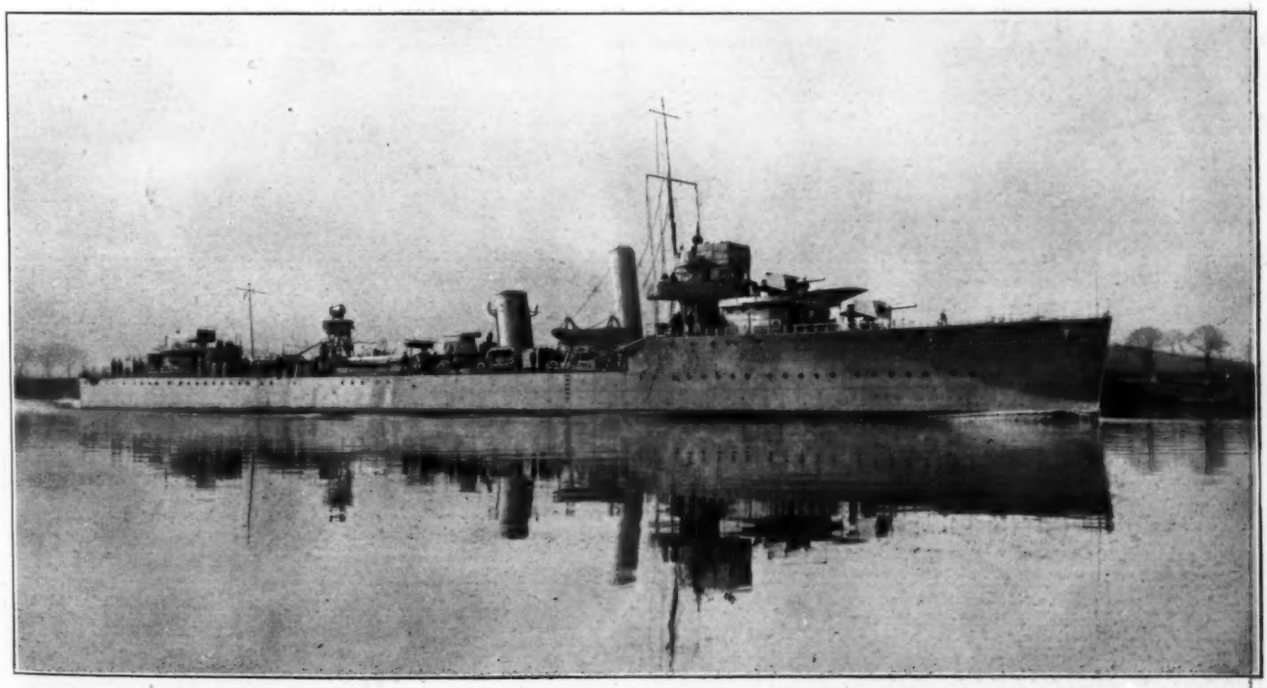


Fig. 6. H.M. Torpedo Boat Destroyer of the "V" Class; Messrs. John Brown and Co., Limited, Clydebank.

THE WAR DEVELOPMENT OF TORPEDO BOAT DESTROYERS.

(*For Description, see Page* 362.)

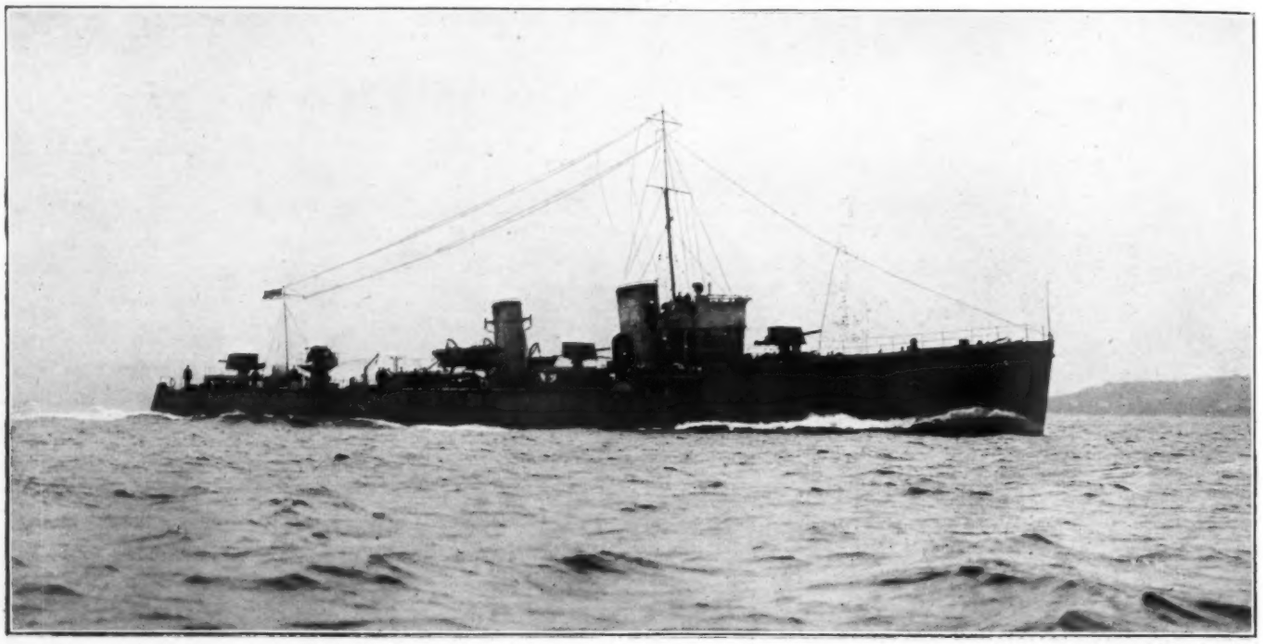


FIG. 7. H.M. TORPEDO BOAT DESTROYER "MIRANDA"; MESSRS. YARROW AND CO., LIMITED, SCOTSTOUN, GLASGOW.

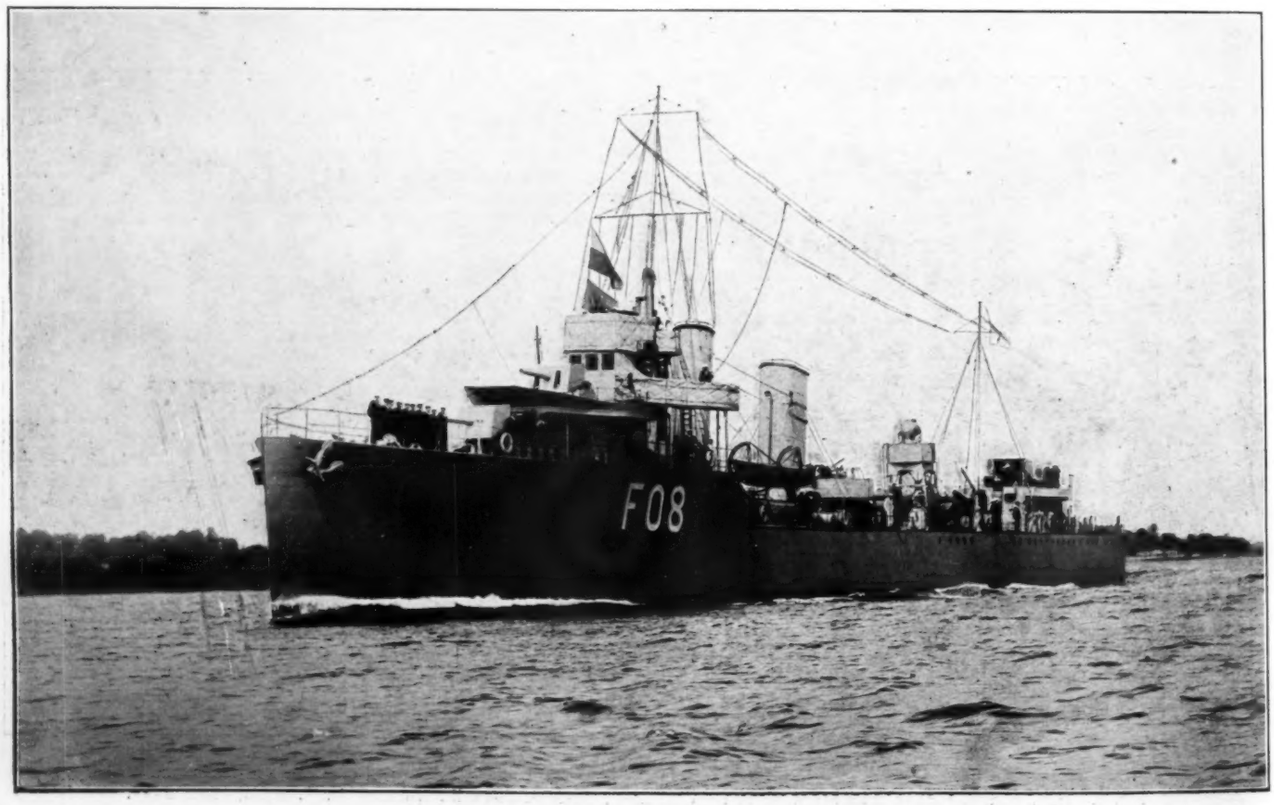


FIG. 8. H.M. FLOTILLA LEADER "SHAKESPEARE"; MESSRS. JOHN I. THORNYCROFT AND CO., LIMITED, SOUTHAMPTON.

(*To face page* 363.)

AGENTS FOR "ENGINEERING."

AUSTRALIA: Gordon and Gotch, Limited, Melbourne; Sydney; Brisbane; Perth. Turner and Henderson, Sydney, N.S.W. T. Willmett and Co., Townsville, North Queensland. W. C. Rigby, Adelaide, South Australia. Melville and Mullen, Melbourne, Victoria.
BELGIUM, Brussels: E. F. Satchell, 86, Rue du Tabellion.
CANADA, Toronto, Ont.: Wm. Dawson and Sons, Manning Chambers. Montreal: Sells, Limited, 302, Shaughnessy Building, McGill-street.
EDINBURGH: John Menzies and Co., 12, Hanover-street.
FRANCE, Paris: Boyveau and Chevillet, 22, Rue de la Banque. For Advertisements, Agence Havas, 8, Place de la Bourse.
GLASGOW: William Love.
INDIA, Calcutta: Thacker, Spink and Co. Bombay: Thacker and Co., Limited.
ITALY: U. Hoepli, Milan, and any post-office.
LIVERPOOL: Mrs. Taylor, Landing Stages.
MANCHESTER: John Heywood, 143, Deansgate.
NEW ZEALAND: Gordon and Gotch Proprietary, Limited, Wellington, Auckland and Christchurch.
NORWAY, Christiania: Cammermeyer's Boghandel, Carl Johans Gade, 41 and 43.
ROTTERDAM: H. A. Kramer and Son.
SOUTH AFRICA: Central News Agency, Limited, Head Office—Johannesburg; and Pretoria, Cape Town, Port Elizabeth, Bloemfontein, Durban, and their various branches and bookstalls throughout South Africa. Also Cape Town: Wm. Dawson and Sons, 31, Long-street.
TASMANIA: Gordon and Gotch Proprietary, Limited, Launceston: Hobart.
UNITED STATES: For Subscriptions, New York: W. H. Wiley, 432, Fourth Avenue.
For Advertisements, J. S. Allan, 18, Broadway, New York.

ADVERTISEMENT RATES.

The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

For the United Kingdom	£2 9 6
For Canada—	
Thin paper copies	£2 5 0
Thick " "	£2 9 6
For all other places abroad—	
Thin paper copies	£2 9 6
Thick " "	£2 14 0

When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford Street, Strand, W.C. 2.

Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand, London, W.C. 2.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3663 and 8596 GERRARD.

CONTENTS.

	PAGE
On Some Principles of Manufacturing Interchangeable Articles to Limit Gauges (*Illus.*)	361
The War Development of the Torpedo-Boat Destroyer (*Illus.*)	362
The Measurement of Fluid Velocity and Pressure (*Illus.*)	364
Spectrum Analysis and Atomic Structure	366
Templets, Jigs and Fixtures.—No. XXII (*Illus.*)	367
Physical Society of London	370
Injection of Water into Internal Combustion Engines	371
"Coal Saving and Scientific Control of Steam Boiler Plant"	371
Naval Engineers (*Illus.*)	371
Sliding Friction in Ball Bearings	373
The Breakdown of the Electrically - Propelled Battleship "New Mexico"	373
Situations Vacant	373
Die Castings and their Application to the War Programme (*Illus.*)	374
The Divisional Engineers of the Royal Naval Division	375
Notes from the North	376
Notes from South Yorkshire	376
Notes from Cleveland and the Northern Counties	376
Notes from the South-West	377
Notices of Meetings	377
Ministry of Ways and Communications	379
Power Distribution by Gas and Electricity	380
Commercial Flying	381
Notes	382
Literature	383
Books Received	384
Industrial Notes	384
Diesel Engine Users' Association	385
Royal Meteorological Society	385
The Hardening of Steel (*Illus.*)	386
Catalogues	390
ENGINEERING Patent Record (*Illus.*)	391

With Four One-Page Plates of the WAR DEVELOPMENT OF THE TORPEDO-BOAT DESTROYERS.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 377.

ENGINEERING.

FRIDAY, MARCH 21, 1919.

MINISTRY OF WAYS AND COMMUNICATIONS.

THE Ministry of Ways and Communications Bill has passed its Second Reading. The outstanding features of the debate on the Second Reading, which took place on Monday and Tuesday last, were the capitulation of the Government upon the clause which proposed to give the Minister power to nationalise railways by an Order in Council and the indication that other sections of the Bill will meet with very severe criticism before the approval of the House of Commons is forthcoming.

Sir Eric Geddes, as Minister designate, made a long statement of the case for the Government, but we are bound to say that in many respects it was far from convincing. In regard to railways, he said that they were to-day being worked at a loss of something like 100,000,000*l.* a year, but he did not make any attempt to demonstrate the accuracy of this estimate. As we have urged on previous occasions, the Government should submit a detailed statement of railway receipts and expenditure for each of the years 1915, 1916, 1917 and 1918, setting out the receipts for passenger traffic, freight traffic, and the estimated value of traffic carried without charge on behalf of the Government, and, on the other hand, the expenditure in the different departments of the railway administration in respect of materials and wages. We have the strongest reason for believing that if such a return were produced—and the figures are known to the Board of Trade—it would show that Sir Eric Geddes would find it impossible to substantiate his statement that there is to-day a loss of 100,000,000*l.* a year in working the railways. But even supposing this estimate to be correct, surely it conveys a warning of the possible results of nationalisation.

For four and a-half years the Government have controlled the railways of Great Britain; under this control enormous economies have been effected, train services have been ruthlessly cut down, canvassing for traffic has ceased, and many other economies which in pre-war days were sought to be secured by advocates of nationalisation have materialised. Against them, however, has to be set the enormously increased cost of operating the railways, due to the fact that labour has found the representatives of the Government far more pliable in responding to its demands than were the railway companies. The war wages alone, apart from standard wages, paid to men in country districts are said to exceed the total wages of agricultural labourers as defined for many counties by the Agricultural Wages Board. Yet as we go to press a situation is developing which, apart from other considerations, is due to the fact that the trade unions of railwaymen are insisting that the extravagantly high war wages should be permanently added to rates of wages. We have thought it well to refer to this aspect of the matter as a warning to the public and the taxpayers that the glowing forecasts as to what is likely to happen when the transport services of the country are nationalised will probably be different from actual results.

Strangely enough, Sir Eric Geddes regarded the one bright spot in the transportation system of the country as municipal tramways. He ignored the fact that in many instances they are a heavy drain upon the rates. Exactly in what way he considered municipal tramways as worthy of commendation did not transpire, unless it was that he was enamoured of the fact that 96 per cent. of them are electrified. Other transport systems, he said, were not prosperous to-day and, as regards railways, he claimed that they were financially in a semi-paralysed state; that their development had been retarded; that capital expenditure under normal conditions had not been undertaken; that they were holding back because they did not know what was going to happen, and that during the war—when, be it remembered, the Government were in control—a dead hand was over them, while for years before a parasitical growth had been enveloping these great undertakings. The Government desired to get railways back to a paying basis and to evolve order out of what was to-day really chaos. This may or may not have sounded convincing in the House of Commons, but it is singularly unconvincing in cold print.

The facts are that in the decade 1903–1912 the railways of this country spent capital to the extent of 99,000,000*l.*, and in the previous decade over 200,000,000*l.* It is quite true that before the war there was a tendency, and, as we believe, a justifiable tendency, to effect economies by working agreements, but the character of the pre-war service and the expedition with which passengers and merchandise were conveyed would not have been regarded at the time as indicating that railways were impeded by anything in the nature of a "parasitical growth."

As regards the period during which the Government have been in control of the railways, no doubt the railway companies would be content to rest on what has been said on a great number of occasions (*e.g.*, in such reports as that of the War Cabinet and of the Committee on Transport) as to the efficiency of the services rendered. We have it, however, that in the view of the new Minister of Transport, there was before the war, a parasitical growth, that during the war there has been a dead hand on the railways, and that the net result of Government control is the reduction of the railways from a paying basis to that of concerns losing 100,000,000*l.* a year. How is this situation to be rectified? The Government's answer is that they have come to the conclusion that some measure of unification of control of all systems of transportation is necessary. It appears that until Sir Eric Geddes went to France, Englishmen did not know what was the "driving, vitalising spirit of transportation—that they did not even use the word."

We do not propose to discuss whether what was done in France was done economically, or, indeed, with conspicuous success, but we submit that what was done during the war and in war conditions can have little or no bearing upon the re-organisation of railway, road, canal, harbour and other agencies on a peace footing.

Sir Eric Geddes seems to be under the impression that the railway companies conspired together in order not to get the shortest haul. "I know of cases," he said, "where goods for northern markets were deliberately influenced to a southern port in order to get the haul over the railway and goods for southern markets were deliberately influenced to a northern port." We should like to know what the shipping interests have to say as to this. We believe that the average shipping company does not part with goods until it has carried them as near to their destination as is commercially justifiable, but the whole matter is bound up with the avoidance of unnecessary transit by sea. For example, if cargo could be landed at Hull and sent by rail to Manchester, it would surely be better to do so than for the vessel to travel three sides of a rectangle in order to convey the goods by water from Hull to Manchester.

Another criticism of the railways was as to dual brakes on rolling stock, which was claimed to be the result of the absence of unified control. We are acquainted with many railway managers who have totally different views. The facts are that, while the Government decided that rolling stock should be fitted with continuous brakes, the Board of Trade refused to take the responsibility of deciding what kind of brake should be applied. This is only one of many directions in which the Government have failed to bring its influence to bear upon standardisation, and even at the present time when much discussion is taking place in regard to auto-

matic signalling, nobody, on behalf of the Government, has had the courage to say, in respect of any one system: "In our opinion this is the best, and should be generally adopted." Time will prove whether the Minister of Transport will be in any respect wiser and bolder than previous Ministers, who have been concerned with railways in their capacity as Presidents of the Board of Trade.

So far as railways are concerned, the situation was summed up by Sir Eric Geddes in the concluding portion of his speech that the railways could not possibly go on for another two or three years in the position in which they are to-day, working under the Executive Committee of General Managers. That Committee had done a good work, of which they are justly proud and for which the country should be grateful, but they were an emergency Committee, they did not really run the railways, they had no power over any capital expenditure, no power to do anything but keep the thing moving. It was to secure economies and development on a large scale that Government control was proposed. If it were suggested that the situation should be dealt with by increasing railway rates by 70 per cent. to 80 per cent. such an increase was unthinkable. It was equally unthinkable that the taxpayer should pay and, therefore, the Government must introduce economies, which were only possible under a comprehensive system of control. Perhaps, he said, the greatest saving of all was the introduction of electricity for haulage purposes—not electricity such as is used in the multiple-unit system on the tubes around London, but electricity used with heavy electric locomotives. The trader also must help, if he does not want to have a 70 per cent. or 80 per cent. increase of rates. He must get his wagons away quicker and learn that storage on wheels is too expensive for the country to afford. He must store in a cheaper way and then, with improved terminals, larger wagons, and empty haulage eliminated, economies could be effected. As regards empty haulage, one of the first steps which the Government would take if the Bill became law would be to acquire on fair terms all the privately-owned wagons of the country with a few exceptions such as wagons for acids and liquids.

We do not propose to follow Sir Eric Geddes further in regard to arguments for and against the Government control of the railways. We have ourselves advocated control. We believe it to be essential in view of the fact that the Railway Companies will not be in a position to raise capital without the aid of the State, and we are satisfied that a well-considered form of Government control should be beneficial, but we strongly objected to nationalisation by Order in Council, feeling satisfied that a much better case than has yet been made out is necessary before the railways should be owned and operated by the State. As we have already stated that part of the Bill which provided for the taking over of the railways by Order in Council has been dropped. It now only remains to be secured that such control as is to be exercised by the Government should be in the best possible form.

Turning to the other sections of the Bill, we think it may safely be claimed that much more convincing arguments and facts must be produced before the House of Commons sanctions the inclusion in the Bill of the control of roads or electricity undertakings. The opposition of road users is insistent, and we sympathise with them. The provision and maintenance of roads is an entirely separate matter from that of railway or canal operation. The setting up, as has been proposed, of a separate section of the Ministry would not be as satisfactory as the course which we advocate, and we shall await with interest the development of the opposition to this section of the Bill. As regards the generation and supply of electricity, we are strongly of opinion that so technical and specialised a matter ought not to be relegated to any Department of a much overburdened Ministry. The problem bristles with difficulties, and should be referred to a body of Commissioners who would really understand it.

It may or may not be the case, as Sir Eric Geddes said, that 20 per cent. of the electric supply of the country could be used for traction purposes. In any case, the provision of cheap electric current should not be the governing factor in deciding whether or not a section of railway should be electrified. That there are heavy and important sections of the railways which could justifiably be electrified is admittedly the case. Sir John A. F. Aspinall has shown what can be done in this way. The electrification schemes of the Lancashire & Yorkshire and other railways showed that in pre-war days there was no lack of initiative in introducing electric traction where it was financially justifiable. The proposal to associate the generation of electricity with what, after all, is a Ministry of Railways, on the ground that railways are large users of electricity, and that railway lines offer a convenient route for cables, is as unconvincing as would be a proposal to place electric generating stations under a Department of Coal Mines, because coal is the primary factor in the production of electric current.

As regards harbours and canals, there is perhaps less to be said. We should prefer that harbours owned and governed by trusts should be undisturbed, but we recognise that the fact that railway companies own many docks and harbours constitutes an argument in favour of their inclusion within the purview of the Ministry of Ways and Communications, and the same reason applies in the case of canals.

To sum up our impressions of the debate on the Second Reading, we think it has been established that the principle of State control of railways and canals, and possibly also of harbours, will be approved by the House of Commons, but any scheme of nationalisation will require to be most carefully considered. That some form of nationalisation may possibly result from the control is clear, because under such a form of control as has been foreshadowed, the property of individual railway companies will be so materially disturbed that in the end of the day it may be impossible to restore them to their original status. This fact is clearly intimated by Sir Eric Geddes's statement that "until the railways have been told one cardinal fact—until they have been told authoritatively and definitely, either that they are to go back as independent concerns, or that their interests are going to be fused, and they will never go back as independent concerns—until they have been told that, we cannot get even the commencement of the economies, because in every case, with the best will in the world, you come up against the fact that the individual interests will not let you go on, and that is the best proof possible of the point which I have been endeavouring to make, that unified control is essential in transportation." It must not, however, be overlooked that if individual railways are to lose their individuality they will require to be informed on what basis they are to be compensated. They are entitled to know whether in the event of nationalisation their property will be acquired on the basis set out in the Railway Regulation Act of 1844, or, if not, what basis will be proposed. This aspect of the matter will, no doubt, crop up in the Committee stage, as will also the question of setting up some Board of Commissioners on which not only the railway interests, but those of traders and workers will be represented. Having said this, we advocate withholding from the new Department any power over roads or the generation and supply of electricity. As has been stated by *The Times*, "the Bill must ultimately involve a fresh imposition of bureaucratic control upon the country at a time when we were hoping to gain some freedom from the shackles of bureaucracy"—but by all means let us restrict this unfortunate development within the narrowest possible limits.

POWER DISTRIBUTION BY GAS AND ELECTRICITY.

THE inefficiency of the power generation methods of this country have long been a matter for discussion and even for agitation among engineers. The large electric generating station has been compared with the small, the qualifications of the individual factory power plant as against centralised supply have been discussed, the gas interests and electrical interests have struggled each to make a better case than their competitor, and the gas engine has fought many a battle with the steam turbine. For long years the public and the politician took absolutely no interest in this question in spite of repeated warnings about our rate of coal consumption and our supply of available fuel, but in the last year or so there has been a remarkable change, and now the public and politician are much alive to the subject. Unfortunately, they now not only take an interest in it, they also appear to know all about it. Apparently the war has made us all into engineers. In virtue of this the country is without further discussion mapped out into electrical districts to be supplied each with power, light and heat from a large central electrical station, and Sir Eric Geddes, with a wave of the hand, electrifies all our railways.

We have taken so large a part ourselves in controversies concerning improvement in power supply methods that no one can suppose we are indifferent to the subject, or fail to realise its importance. All the same we trust steps of the magnitude proposed are not going to be taken in the same spirit and slap-dash way in which a motor or repairing depot is built at Slough, or a large section of one of our biggest shell factories is converted for gun re-lining only to be re-converted back to shell manufacture before the first gun had been turned out. Electrical engineers have taken much part in the discussions concerning power supply in the past, partly undoubtedly because their own business, aided by legislative shortsightedness, has furnished such an excellent example of how not to do it, and they now appear to have come into their reward. Electricity has always captivated the public as something you could do anything with, and it has now apparently won all along the line and we are to be electrified from attic to basement.

Be the outcome of the present coal difficulties what they may, there is no doubt but that coal will be dearer in the future than it was in pre-war days, so that anything tending to its economy is of the first importance. Also the question of the exhaustion of our coal measures cannot be ignored. Sir Dugald Clerk, speaking at the Royal Society of Arts on the 19th inst., estimated that our coal measures at the present rate of use would last 500 years, but if the rate of increased use continued they would last but 200 years. Five hundred years is a long time to look ahead, but the beginning of an exhaustion culminating in 200 years might affect one's great grandchildren. On all hands economy in power generation and distribution and employment is of the greatest importance, and it is precisely for this reason that it is to be hoped that Government will not force these electrical proposals forward to accomplishment until they have really inquired into and determined the best methods of tackling the problem they are faced with.

In many ways electricity has advantages over its competitors and in, for instance, the economical running of a railway, speaking solely from the fuel point of view, it has no rival. In domestic service its advantages over its competitor, coal gas, are more those of convenience than economy, and we believe, especially for heating, that gas makes the better showing, speaking again from a coal conservation point of view. In discussing this subject, it is always well to remember that to save coal is not necessarily to save money; capital charges on auxiliary services may cost more than the fuel saved. It is impossible, however, to discuss this subject fully in a short leader, and our present purpose is more particularly to call attention to an excellent case for gas as opposed to electricity for the supply of power, heat and light, which was made by Sir Dugald Clerk at the meeting to which we have already referred. Sir Dugald throughout dealt with his subject purely from the coal conservation point of view.

The gas industry of the United Kingdom, Sir Dugald stated, carbonises about 20,000,000 tons of coal per annum of an average calorific value of 13,000 British thermal units per lb., and the thermal efficiency of carbonisation is about 71 per cent. That is to say after completion of the process the three main products—coal gas, coke and tar are capable of evolving, on complete combustion, 71 per cent. of the original total heat of the coal. Of this 25 per cent. is obtainable from the coal gas and 46 per cent. from the tar and coke. If one considers the whole of the heat lost in carbonisation, amounting to 29 per cent., should be debited against

the gas which is the principal product; then to obtain 25 heat units with the form of gas it is necessary to use 25 + 29, *i.e.*, 54 heat units of the original coal. The thermal efficiency of the gas-making process is accordingly 46 per cent. If the whole of the gas produced be completely burned the heat evolved will equal that which could have been produced by combustion of 25 per cent. of the original coal, *i.e.*, 5,000,000 tons. But the efficiency of gas production is 46 per cent., so that 10·9 million tons of coal is used in the process, leaving still a heat equivalent in the remaining coke and tar of 9·1 million tons of the original coal.

Turning, then, to the conversion of coal to electricity, Sir Dugald stated that, according to Mr. D. Wilson, the technical adviser to the Coal Controller, the electrical industry of the country, in the year ending March, 1918, generated 4,674,000,000 units on a coal consumption of 3·47 lb. of coal per unit, the calorific value of the coal being 11,600 British thermal units per lb. The total consumption of coal in the year was 7·3 million tons, and the thermal efficiency of generation, 8·5 per cent. As the coal is of lower thermal value than that used for gas making, an adjustment is necessary which brings the total consumption to the equivalent of 6·5 million tons of gas coal. As the amount of heat which could be generated by the electrical energy actually produced is 8·5 per cent. of the total heat in the coal used, it follows that the same heat could be produced by the combustion of 0·55 million tons of 13,000 British thermal unit coal. Comparing this figure with that already obtained for the gas industry, it will be seen that at present the capacity for heat production of the gas industry is nine times the capacity of the electrical industry, and the thermal efficiency of the generation of heat by gas is over five times that of its generation by electricity.

Proceeding then to distribution and consumption, Sir Dugald took the efficiency of distribution in both cases at 90 per cent., and went on to point out that for domestic heating and cooking an examination of the efficiencies of gas fires, as contrasted with electric radiators or heaters for cooking, &c., showed that in heating rooms, 27 heat units applied to raising a room temperature by radiation and convection required the use of 100 units at the gas works, while electricity only supplied 7·6 heat units to the work for a consumption of 100 units at the generating station. Similar figures were for boiling water, 22·5 units were supplied by gas against 3·8 by electricity, in both cases for 100 units at the point of generation. For cooking, the figures were, gas 3·4 units, against 1·5 for electricity, and for metal melting 14·4 for gas, against 4·1. The average figure for consumption at the point of generation varied in the case of electricity from 2½ to about 6 times above that necessary for gas for heating services. A good all-round figure was probably 4. From this it was obvious that if heating service was in general to be carried out by electricity, the consumption of coal would be very seriously increased.

In the case of lighting, the two services were very much on a parallel. The inverted incandescent burner used 47 British thermal units at the gas works for each candle-power hour obtained by the consumer, while the 1-watt electric lamp required 54. The ½-watt lamp, however, brought the electrical figure down to 31. High-pressure incandescent burners reduced the heat consumption to 23 British thermal units, but were, of course, only available in fairly large powers, and electricity could also show a better figure for large lighting units. Referring next to motor power, we should, perhaps, again emphasize the fact that these figures of Sir Dugald Clerk's refer only to coal consumption, which has been put forward as one of the main arguments in favour of general electrification. As may be expected when the power question was considered, the figures again came out in favour of gas. Briefly, the position was that a gas-engine at 75 per cent. full load would deliver as brake horse-power, 11 per cent. of the heat used at the gas works to produce the gas, while the electric motor could only produce 6·8 per cent. of the heat used at the generating station, showing an efficiency of gas 1·6 times that of electricity.

The figures above referring to gas have been taken out on the assumption of a thermal efficiency of carbonisation of 71 per cent., but Sir Dugald quoted cases in which efficiencies of 82·2 per cent. and 82·7 per cent. have been reached. If we are to have a thorough overhaul of all our methods there is no reason then why the average should not be raised above 71 per cent. It is to be noted that the super-electric-power stations which we are promised are credited with a thermal efficiency 1·5 times that of the best existing practice and 2·3 times the present average. Taking the figure given, however, and assuming that the average thermal efficiency of carbonisation at gas works is raised to only 75 per cent., which Sir Dugald considers very possible, he then showed that for heating, from the coal consumption point of view, gas would still beat electricity in the ratio of 3·8 to 1; for lighting the 1-Watt lamp would beat the inverted mantle, but for power gas would show a thermal efficiency of 17·5 per cent. as compared with one of 15·9 per cent. for electricity.

This important and complicated question of power and heat supply cannot be settled purely by a consideration of thermal efficiencies and coal consumption, but the supporters of the proposed large generating stations have largely based their arguments on those grounds. Sir Dugald Clerk's paper formed an admirable reply. It is not very clear what is in the minds of the members of Government in reference to the matter or if ideas are crystallised at all. But in some quarters one gathers that the use of electrical energy is proposed to be made compulsory and that competing methods are to be eliminated by legislation. One can hardly think that likely, but can cordially agree with Sir Dugald Clerk when, speaking of gas engines, he says, "It would be a most serious matter for the country if the development of these engines be hampered in any way." It would also be a most serious matter for the country if we tied ourselves to a cut and dried method of power production and ruled out alternative methods on the score of saving coal or anything else.

COMMERCIAL FLYING.

PROPHESY is very busy these days with the future of the aeroplane and airship, and its vision is apparently limited only by the upper atmosphere. It needs but little study of some organs of the Press and one may see visions of pantechnicon vans careering overhead between London and Brighton, and the baker, for some inscrutable reason, delivering his goods to the householder by aeroplane—presumably dropping them into the back yard. All this sort of thing is very pretty and very exciting, but it sounds a little uncommercial, not to say unnecessary. In suggesting the value of a little cold water on some of the present enthusiasm we are not losing sight of the fact that it is less than ten years since Bleriot flew across the Channel, and that the art of flying has since then shown a rate of advance which it would be difficult to parallel in the history of the mechanical arts. This, however, is no proof that flight is to be the method of travel and transport *par excellence* of the future.

We, at least, have no wish to pretend to tell what vistas the advance of the future may open. The apparently impossible may become the commonplace, and the babe in arms take to the air like the duckling to water—we do not know. The things of the future must be left to the future. What one can do, however, is to attempt some estimate of the commercial possibilities of flying from the point of view at which we now stand. Some assistance in this task is, we think, likely to be given by a consideration of the relative merits of the present forms of transport—the merits which have raised each to the position it now holds. The railway beat the packhorse, the wain and the canal because it was more speedy and could deal with enormously greater bulk and weight of material expeditiously and at reasonable cost. In that it is tied to a definite track the railway is inferior to the packhorse and to a less extent to the wain. The canal, equally with the railway, is tied to a definite track, but the railway beat it, at least in this country, on the score of speed and cost. The motor vehicle now to some extent menaces the railway. It has equal and sometimes superior speed and is not tied so rigidly to a track. At sea the situation is simpler; one has but the sailing vessel and the steamship. Speaking quite generally the steamer has beaten the sailing vessel on speed and on freedom of movement, since in its dependence in many trades on prevailing winds the sailing ship is in effect tied to a definite track.

Into this arena of competitive transport methods the aeroplane and airship are now introduced, and one may ask what their peculiar qualifications are as compared with existing services. In that they have superior speed over all existing transport methods and are not tied to definite routes they are apparently superior to all. Apart from the cost factor, however, the matter is not quite so simple as this. If one considers the aeroplane from the point of view we are now taking, it may fairly be looked upon as an example of a glorified motor vehicle. The railway train is confined to its rails, the motor car is freer than this but still is, commercially at least, confined to fairly reasonable roads, the motor bicycle is still freer and can go where the motor car cannot, while the aeroplane transcends them all and goes where it wills. If there is anything in the parallel between the motor vehicle and the aeroplane one might expect to find them operating in the same spheres, and as far as the immediate commercial uses of the aeroplane are concerned that is exactly what one does find. In the carriage of mails, in pleasure work, in the administration and exploration of far countries one has spheres already covered to some extent by the motor vehicles and which there are signs of the aeroplane now invading.

No better idea of the justice of the parallel between the aeroplane and the motor car and motor bicycle could be given than by a consideration of Major-General Seely's statement on the Air Vote in the House of Commons on the 13th inst. That statement covered much of great interest concerning the military work which has been done, but with that we are not for the moment concerned. On commerce flying, or civil aviation, or whatever one cares to call it, General Seely's recital confined itself in the main to the question of the carrying of mails and the administration and exploration of undeveloped or partly-developed country. In connection with mail carrying he referred specifically to a proposal for a mail service between Cairo and India. He characterised the possibilities of the proposal as extremely favourable and stated that an estimate by a responsible officer showed that the service would be profitable. As the Postmaster-General was also stated to have gone into the matter and to be enthusiastic in support of it, the service is likely to be given a trial. It is very desirable that it should in order that some idea of the cost and commercial practicability of this kind of work should be established as soon as possible. Concerning the value of the aeroplane for administrative and other work in far countries, General Seely made the interesting statement that our Political Officer at Baghdad reported he found he could in two days carry out inspections and other work which previously had taken him two months. This is a field which one may expect to see greatly extended in less-developed countries and those of large area, but scattered population.

In addition to those types of commercial aeroplane service referred to by General Seely we have also mentioned pleasure traffic as a likely field for immediate development. The matter is a fairly obvious one, and we see no reason why a start should not be made at once. Some of the projected services in connection with watering-places should prove very popular and should furnish valuable financial data for further development. This class of work is of course again an example of extension in a field already served by the motor vehicle, and it is interesting and suggestive that all the commercial aeroplane service in being or apparently likely to be in being in the near future is an extension of services already covered by the motor. We do not suggest that the aeroplane may not ultimately force its way into entirely new fields, but clearly its immediate development lies in the greater exploitation of fields already partly worked by the motor car, which from an abstract traffic point of

view it may be looked on as a development of. Before leaving the matter we should perhaps mention express passenger services between important centres as a reasonably likely development of aeroplane service. In this work the aeroplane would appear to be entering the field of the railway rather than that of the motor car. But actually this is a railway field which the motor car has already invaded and the aeroplane would merely develop and carry on a movement already started.

When one attempts to look at the possibilities of the airship from the same point of view which we have taken in regard to the aeroplane, it is less easy to determine its position in respect to other modes of transport. Considering oversea service, which is for the moment the most promising field as far as this country is concerned, one would naturally, in view of its great speed, look upon the airship as a development of the steamer rather than the sailing vessel. None the less, in its regard for prevailing winds the airship has perhaps more in common with the sailing ship than the steamer. In projected Atlantic services it is proposed that the westbound journey should be made by a southern route *via* Portugal and the Azores in order to some extent to avoid the prevailing westerly winds. Heavy storms, fogs, &c., affect all shipping to some extent, but will probably effect the airship to a greater extent than the steamship. It is estimated that with the airship as at present developed flying over the Atlantic would be possible on about 82 per cent. of the days of the year. The development of the airship may, of course, increase this percentage, but even as things are a greater regard for the weather is not likely to prevent the airship from competing with the steamer in certain fields. In spite of its dependence on the weather the sailing vessel has made a good fight against the steamer, and in view of the rising costs of fuel there would be nothing surprising in a great revival of the sailing ship in certain trades. The immediate commercial field for the airship would appear to lie in the development of long-distance passenger services. Such remarkable improvement over existing times could be shown that high fares could without a doubt be obtained. Of the desiderata towards putting the airship on a commercial basis the most important at the moment is probably the starting of a service in some form, in order that the public may have practical demonstration of its possibility and gain confidence in its safety.

We have attempted so far to refrain from dealing with the commercial possibilities of flight in terms of unknown developments of the future. What the art now requires is application of what we know, not speculations about what we don't. None the less, progress there will be, particularly in our opinion in the next few years in respect to the airship rather than the aeroplane. Mr. Joynson-Hicks, in the discussion following Major-General Seely's statement in the House of Commons, stated that he believed that the progress in aviation in the last five years, great as it had been, would be nothing compared with the progress of the next five years. It was not clear if Mr. Joynson-Hicks was referring to aeroplanes or airships, but from the context he would appear to have referred to aeroplanes. If this was so, we think he was overestimating the likelihood of future progress. It would not be surprising if the aeroplane proved to have already settled down to approximately its final form, and if developments for many years were restricted to engine and other details.

The air-ship however, is in a somewhat different position. Its development was not assisted by the enormous body of workers and the quality of war stimulus which had so much to do with the amazing progress of the aeroplane. The airship, moreover, to give its best efficiency, must be very large, and consequently experiment has been more difficult and costly. General Seely quoted Sir Charles Parsons in connection with this matter to the effect that the tractive power, of an airship, required to pull a given load, given the same speed, varied almost exactly inversely with the size of the vessel. Sir Charles had also pointed out to General Seely that this was also true to some extent of sea vessels, but that designers had always been limited by harbour accommodation. Difficulties of that order disappeared with airships and enormous developments were possible. Without carrying speculation beyond fast passenger services and the carrying of light but valuable cargoes, it is clear that with a development in size and a falling running cost, great progress may be made with airship services. It is well, however, for the present to assume that the services would be relatively costly and that passengers would be prepared to pay for the great time-saving.

One must not suppose that any steamship service can be successfully competed with. Major W. T. Blake, writing in *The Sunday Times* of the 16th inst., referred to Australia as a great airship centre of the future. The country may become so, but when Major Blake reinforces his argument for airships by contrasting their speed with that of the present steamship services radiating from that country, we fear he is not speaking from the point of view of commercial aviation. He says "steamship lines undoubtedly follow all these routes, but at what speed? Probably an average of 12 knots would not be far out. The big airship will cover the distances at an average of at least 70 miles per hour." This quotation raises the commercial aspect of the question in a very definite form. Twelve knots may be a fair average for Australian steamship services, but if it is, it merely shows that that is the greatest speed the traffic warrants. The steamship is not limited to 12 knots, and if the Australian services admitted it, there is no doubt but that we would see the speed raised 50 per cent. or more. Unless airship services are to be run at a loss the routes chosen must be such that a comparatively expensive and continuous passenger traffic can be cultivated.

Before concluding, we must refer to General Seely's statement that a sum of 2,000,000*l.* was to be granted for research and other work in connection with the development of civil aviation. We doubt if any single fact could more markedly indicate the progress since 1914 which the country as a whole has made towards a proper recognition of the importance and value of scientific research. In the year ending March, 1914, the total Treasury grant to the National Physical Laboratory was only 12,000*l.*, to cover all branches of work, which appears now a ludicrous figure as compared with the 2,000,000*l.* to be devoted to one subject alone. We are not, of course, suggesting that the National Physical Laboratory will have the spending of the whole of this sum, but it will undoubtedly obtain a large share. As we understand General Seely this sum is independent of expenditure in connection with meteorological research which will benefit both military and civil aviation, and which still offers an enormous field for work. A final matter calling for mention is the inauguration of an Aviation Insurance Association in connection with Lloyd's. This is an earnest that the business world is prepared to take commercial flying seriously. This association, in conjunction with a registry which is likely to be established, will do much to put the new industry on a proper commercial basis, and will encourage capital to enter the business.

NOTE.

GASES AND VAPOURS FROM GLASS.

THE gases and vapours which are liberated from the inner walls of an evacuated system are a source of much trouble in researches conducted at very low pressures, such as the modern high-efficiency pumps permit of producing. The vessels used in high-vacuum research are practically all made of glass, and it is common practice to heat these vessels, while being exhausted, up to temperatures of 450 deg. C., in order to expel the gases adhering to the glass walls. We recently noticed an investigation of the measurement of high vacua,* conducted by Shrader and Sherwood at the Westinghouse Research Laboratory. The *Physical Review* of December, 1918, contains a further article by R. J. Sherwood on "The Gases and Vapour Liberated from Glass." The conclusion arrived at is rather novel and may be contested. Sherwood assumes that the gaseous evolution from heated glass is of two distinct kinds: there is, first, liberation of the adsorbed layer of air, moisture, &c., which takes place at 200 deg. C.; and, secondly, a further more important evolution of gas at a higher temperature, which depends upon the formation of a new chemical equilibrium. No suggestion as to the nature of this equilibrium is made so far, and the chief interest of the research lies in the nature of the experiments and in some of the other results. The apparatus used by Sherwood is made of a glass known as Corning G-702-P glass, a material of high-melting point, which is also distinguished by a very small expansion coefficient and very suitable therefore for evacuation systems. The sample container is placed at the end of the apparatus. Next to it is a Knudsen vacuum gauge; then follow a stricture, consisting of capillary tube, about 3 mm. long, and 1 mm. bore, a liquid-air trap, a mercury cut-off and the mercury diffusion pump. The pump itself can—together with the rough pump or Trimount oil pump—discharge up to 4,000 cub. cm. of air per second. The stricture mentioned was introduced to reduce and to regulate the rate of evacuation, and also to facilitate the sealing off of the sample container from the evacuating system. The apparatus is first exhausted, while all parts, except the container, are heated with the Bunsen burner. When the evacuation has been carried to the desired degree, the container is also heated. Various glass materials were used for the container. The gas given off by the glass is condensed in the liquid air trap; the liquid air is then removed, so that the residual gas can be reabsorbed by the container wall. The process is afterwards repeated at higher temperatures. Sometimes the glass was annealed at different temperatures—210 deg. C., 350 deg. C., 510 deg. C., 600 deg. C.—either at atmospheric pressure or in a high vacuum. The samples were then exposed to room temperature for minutes or days, and again heated to various degrees. The atmospheres experimented with consisted of dry air, moist air, and mixtures of carbon dioxide and oxygen. Of these gases, CO_2 was liberated by heat at the quickest rate almost at once. When the CO_2 liberated had been condensed, the pressure rose again slowly, owing to the further liberation of the oxygen or air. Water vapour was retained by the glass surface with much greater tenacity, and moist air also leaked off much more slowly than dry air. It was this observation which suggested to Sherwood that the chemical affinity between the glass and the gas or vapour was a factor to reckon with. That water attacks glass has, of course, long been understood; the surface condition of the glass is a very important factor in that corrosion, but Sherwood does not allude to these features. From his quantitative measurements he concludes that the film of adsorbed gas or vapour has the depth of one molecule only, and that the volume of the film gas and vapour, which comes off at, or even below, 200 deg. C., is small compared to the volume of decomposition products from the glass liberated at higher temperatures.

* See ENGINEERING, December 13, 1918, page 687.

"WAYS AND MEANS."—The first issue of Mr. Ernest J. P. Benn's new weekly, *Ways and Means*, was issued last Saturday. Among the contents are: "The Responsibility of Trade Unions towards Industry," by the Right Hon. J. R. Clynes, M.P.; "Industrial Councils," by the Right Hon. J. H. Whitley, M.P.; and numerous articles by authorities on current industrial topics.

THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.—It is announced that owing to the possibility that the majority of the members of this Institute may be engaged on Saturday, March 22, and in view of the present situation at collieries, the meetings announced to take place at the Danum Hotel, Doncaster, on March 22, will be postponed till Saturday, April 5.

PERSONAL.—At a meeting of the Executive Council of the British Federation of Iron, Steel, Tinplate and Metal Merchants (Incorporated) on the 18th inst., at which Lord Brassey presided, the Secretary, Mr. C. T. Evennett resigned his position. The resignation was accepted with regret, and Sir Johnstone Wallace, the Chairman of the Council, and others, spoke in appreciation of Mr. Evennett's services and stated that he had worked very hard indeed in the interests of the Federation and had been up against great difficulties in organising the Federation during war-time.—The announcement is made that Mr. Alexander Johnston, J.P., General Manager of the North British Rubber Company, Limited, has joined the board of the company as managing director.

LITERATURE.

The Production and Treatment of Vegetable Oils: including Chapters on the Refining of Oils, the Hydrogenation of Oils, the Generation of Hydrogen, Soap-making, the Recovery and Refining of Glycerine, and the Splitting of Oils. By T. W. CHAMBERS, B.Sc., A.M.I.Mech.E. London: Constable and Co., Limited, 1918. [Price 21s. net.]

THE manufacture of oils, fats and waxes or their extraction from vegetable products is not entirely a chemical industry, as some text-books would persuade us; the mechanical side is of quite equal importance, though its progressive development is the work of the engineer alone, and this is true whether the extraction is effected by mechanical means or by the action of solvents. Construction and adaptation of machinery demand a knowledge of physical processes, and are the outcome of mechanical experience. The theoretical investigations conducted in the laboratory may suggest the treatment to be applied, but do not indicate the form or the nature of the appliances necessary to give those suggestions a practical form. In oil machinery the engineer has large scope for originality in design and ingenuity in economical arrangement. If pressure is employed as the means of extraction, the principle is that followed ages before chemistry took shape, and taught the composition of oils, or the value of catalysts. The ancients used a screw press for the recovery of olive oil, and the same mechanism does its work to day, if less effectively, and on a smaller scale than would satisfy modern requirements. What improvements have been made have all been of the nature of details, and these have been the work of the engineer. The problems of bringing greater crushing force to bear, to use power more economically, to make the extraction more effectual, have all been essentially engineering problems, and it is precisely this aspect of the industry that the author of the work under notice explains and illustrates. We congratulate him on having achieved a success of no mean order.

Looked at as a whole the book, the contents of which originally appeared as a valuable series of articles in our contemporary *The Engineer*, is much more interesting than the sum of its parts. The descriptions given assume at times the appearance of a manufacturer's catalogue, describing exactly the machinery designed to effect a particular purpose, or show how firms who have made a speciality of seed-crushing machinery effect similar purposes by different methods. Considered less superficially, one must be impressed by the manner in which a large industry has been built up and a great trade developed. Ingenuity and enterprise have combined to secure this result. The world has been ransacked to find a supply sufficient to meet the demand. The waste, or at least the ungarnered products of one-quarter of the globe, and the sedulously cultivated crops of another have been placed under contribution to swell the available amount of raw material, for its character seems to be of less importance than its quantity. Varying the treatment furnishes new products for which new uses are readily found. The book, therefore, though addressed mainly to the engineer expert, is of value to all who are interested in the economical development of natural wealth, and would learn how increasing demand from a growing population can be satisfied as easily and as satisfactorily, as when that demand was smaller. It would seem as if demand acted as a stimulus to invention and that productiveness was unending. How many outside the particular trades interested know that the importation of the Soya bean into Europe, an unexpected outcome of the Russo-Japanese War, has given an impetus to the manufacture of linoleum, and in the recent scarcity of fodder, the residue after extraction of the oil has provided sustenance to starving cattle. Cotton-seed oil is only a name to most, and few appreciate how much of this edible oil reappears in the form of margarine, the despised but valuable substitute for butter, that in the absence of animal fats has proved so great a blessing throughout the war. It is not Mr. Chalmers' object to dwell on these topics, but to show how machinery can be devised to produce ingredients in a form the most suitable for subsequent treatment.

Looking, however, a little under the surface, we see the need of an instructed public if we are to reap the full reward of our enterprise in the past, and our active exertions in the present. Without the provision of proper precautions to secure an adequate supply of raw material, we may be easily robbed of a large and increasing industry with wide ramifications, that supports no inconsiderable number of workmen, and yields products that minister to the health and comfort of the public. Germany, by its domineering policy of peaceful penetration, or of bullying swagger, had secured virtual monopolies in parts of the world to which access was limited or difficult, that restricted our supplies of certain varieties of fatty vegetable oils. Such sources of raw material have now largely been set free, and we hope will not pass again into enemies' hands, but the surest means of avoiding such disaster is the existence of an informed public alive to the necessity of preserving the command over indispensable materials, and determined to hold the key of the position in spite of the outcry that may be raised by an interested or ignorant faction.

The plan of the book is designed to exhibit the construction of the machinery required for the successive processes of oil extraction and to demonstrate the fitness of each part to perform the work intended. First the seeds, or parts of the plant containing oil, have to be reduced to a form suitable for treatment in the subsequent oil-recovery process; next, by moulding machines, uniformity of size and composition has to be given to the "meal," which is submitted to oil presses, whose function it is to force the oil from the "meal" under pressure. Or, alternatively, the oil may be extracted from the "meal" by means of chemical solvents, the volatile solvent being driven off in a heated still and the oil left behind. By whichever method the oil is obtained, it has to be refined, but in his descriptions of the processes employed, the author is hampered by the secrecy practised in many workshops. In ridding the crude oil of impurities, there is great scope for the ingenuity of the chemist, and the general tendency is to treat each oil in a manner special to itself. The object is to get rid of the colouring matter, which may be derived from the husk, and the vegetable fibrous matter or mucillage crushed out of the seed and held in suspension. Mechanical processes of filtering may be sufficient to get rid of such impurities, but the neutralisation and removal of the free fatty acid, an objectionable product of hydrolysis, that renders the oil liable to decomposition, calls for more elaborate treatment. The extraction of stearine and other glycerides, as indeed oil refining generally, may be regarded as constituting a distinct industry, and on this ground the author may be justified in dismissing the subject very briefly. The four last chapters, which might have been extended with advantage, relate to the hydrogenation of oils, the methods of generating hydrogen for oil-hardening purposes, the manufacture of soap, the recovery of glycerin, and the splitting of oils.

This is a large programme, and in some parts it is not adequately or exhaustively covered. The description of some processes is omitted, but it is easy to err on the side of over elaboration. The author's aim, and one in which he is successful, is to give an intelligent view of the general principles to be observed, not to present all the projects that have been submitted to a long-suffering Patent Office. There may be, for example, 50 methods by which hydrogenation may be effected, many of which have never yielded satisfactory results from a commercial point of view. On chemical considerations they may be suggestive, but writing for engineers, it is far better to follow the steps of one process carried to a successful issue, than to be buried under a mass of bewildering details from which no definite scheme emerges.

The increased demand of late for fatty vegetable oils, as shown particularly in the enlarged margarine industry, raises the question of the better method of extracting the oil from the seed, whether by hydraulic pressure, or by the use of chemical solvents, such as benzene, or carbon disulphide. Two distinct principles are involved in this question, and each has many supporters, among whom may be found many representatives of the agricultural interest. The author sums up the arguments in favour of each with commendable fairness, but we gather that the chemical process meets with his approval, as it would of most engineers on the ground that the solvent plant is cheaper to construct, and simpler to work, requiring less power and less skilled labour. In the "cold drawn" oil process, which on several grounds is the more suitable method where edible oils are concerned, a considerable quantity of oil is unavoidably left in the seed after pressure. Practically, in order to recover the oil, the cake is broken up, submitted to heat, and a "second expression" oil extracted, but though this process may be repeated again and again, it is impossible by crushing processes alone to recover more than 90 per cent. to 95 per cent. of the oil contained in the seed. When benzene or some other solvent is used it is possible to extract as much as 99 per cent., leaving the residue of the seed in practically a dry state. If this were the last word, the advocates of the solvent process would win their case, but at this point the value of the cake complicates the issue. Rape and castor oil seed, with perhaps some others of less consequence, may be dismissed from the controversy, for the residues contain poisonous ingredients that unfit them for fodder, and these can be used only for manures. Obviously, in such cases it is desirable to extract all the oil possible, more especially as the presence of oil in a fertiliser serves to defend it against the attacks of those organisms which convert the fertilising constituents into soil food. But in the case of other oil cake, some urge that the oil is extracted so effectually that the residue has no food value for cattle, and that if some oil is left in the cake, so also is some of the solvent employed, and that this remnant left gives rise to a nauseous smell and taste, that cattle refuse to eat the cake. With regard to this last objection we may say quite distinctly that it is clearly the duty of the chemist to adopt methods that will ensure the entire removal of the solvent. We are prepared to accept the author's statement that such objections do not apply to British-made plant using benzene, and that such statements are in direct conflict with established fact. But unfortunately agriculturists themselves do not appear to be agreed on the value of oil in cattle food. The presence of a marked percentage of oil is not regarded as great an advantage as it was at one time believed to be. A recent report of the Government Committee on oil seeds recommends a cattle food of extracted meal, even when comparatively free from oil, on the ground that while oil is a heat former it is the albumenoids in the material that are valuable from the flesh-forming point of view. The grounds for a very pretty controversy exist, but nevertheless, important as illustrating the interlocking of distinct industries and the need of the engineer to be able to accommodate plant to meet the needs that arise with the growth of science or the variations of markets.

There are many topics to which we should have wished to refer as illustrating the author's breadth of view and his mastery of the subject, but to do justice would occupy too much space. From a purely commercial aspect, the discussion of the palm oil trade is interesting as showing the influence and the disappearance of German control, synchronising with coming changes in the local treatment of palm kernels, to ensure a continuous working of the palm oil trade. This extension is to be encouraged owing to the impossibility of shipping the whole fruit to Europe, on account of rapid deterioration. Engineering criticism is exhibited by the comparison instituted between the relative advantages of the Anglo-American and the cage type of press. In the former, adapted for dealing with seed containing but a moderate amount of oil, the cake of meal is pressed only on its two faces and not simultaneously round the edges. The box-cage press, especially designed to treat very oily seed, apparently surmounts this difficulty, by supporting the layer of meal at the edges while pressure is applied. But other disadvantages become apparent, and the cost of construction is higher.

A clear, if short, explanation is given by the author of the principles of hydrogenation, showing how the superabundant supply of liquid oils is made to compensate the world's deficiency of

natural fats. The catalytic reduction of unsaturated carbon compounds by the direct action of hydrogen in the presence of a finely divided metal, as nickel, has worked a metamorphosis in the industrial possibilities of several trades, but the extraordinary differences in the activity of the metal produced under various experimental conditions has delayed progress. The description of the Lane process, which indicates the nature of the difficulties that had to be overcome to ensure commercial success, is highly instructive and valuable.

A Small Book on Electric Motors for Continuous and Alternating Currents. By W. PERREN MAYCOCK, M.I.E.E. London: Sir Isaac Pitman and Sons, Limited, 1, Amen Corner, E.C. 4. [Price 5*s.* net.]

THE widespread application of electric motors to driving machinery, not only in industrial concerns, but in agricultural, office, and even domestic work, must have become apparent to almost every member of the community. Among them there is probably a very considerable number of people who take a general interest in the working of such appliances, but do not wish to make so deep a study of the subject as would be required for the perusal of standard text-books. To such persons, and to the younger students of mechanical engineering, the little book we are now considering may be confidently recommended. After first pointing out the advantages of the electric motor and giving a brief general explanation of power transmission by electric means, the principles of the continuous-current motor are explained and the construction of typical machines described. Methods of starting and regulating continuous-current machines are dealt with rather fully, and we then find a brief explanation of the fundamental phenomena of alternating currents. Such matters are by no means easy to explain to the non-technical reader, but the author deals with choking coils, auto-transformers and double-winding transformers in a simple manner, which should convey sufficient information for the purpose he has in view. In dealing with single-phase and polyphase induction motors the author has, of course, to assume the existence of a rotating field in the stator, as to explain its formation would be rather beyond the scope of the work. For a similar reason the reader has to take it for granted that the presence of a rotating field will cause the rotor to revolve. These limitations, we fear, impose rather a severe strain on the imagination of the reader, but at the same time we fully appreciate the difficulty of the author's task. Possibly a perusal of the present work will arouse the reader's interest sufficiently to induce him to consult the more advanced text-books referred to, in which these matters are explained. If so, he will find nothing to unlearn, and thus the little book may do much to spread information on the subject. In any case the careful reader will gain some little knowledge of the construction and working of motors, and whether this will prove useful or dangerous depends only upon himself.

BOOKS RECEIVED.

Oxy-Acetylene Welding of Copper, Brasses and Bronzes. By M. R. AMEDEO. Translated with additions by D. RICHARDSON, Wh.Ex. London: Raggett and Co. [Price 2*s.* 6*d.* net.]

Elements of the Electromagnetic Theory of Light. By LUDWIK SILBERSTEIN, Ph.D. London: Longmans, Green and Co. [Price 3*s.* 6*d.* net.

The Manufacture of Aluminium, with Full Notes of Aluminium Alloys, the Analysis and Examination of Aluminium Works Materials, and the Manufacture of Carbon Electrodes. By J. T. PATTISON, F.C.S. London: E. and F. N. Spon; New York: Spon and Chamberlain. [Price 7*s.* 6*d.* net.]

Mnemonic Notation for Engineering Formulæ. Report of the Sciences Committee of the Concrete Institute. With Explanatory Notes by E. FIANDER ETCHELLS. London: E. and F. N. Spon; New York: Spon and Chamberlain. [Price 6*s.* net.]

CANADA—TRACTION ENGINES EXEMPT FROM DUTY.—It is stated in Customs Memorandum No. 2,280 B, says *The Board of Trade Journal*, that, under an Order in Council, authority is granted for the remission and refund of the Customs Duty on gas or gasoline traction engines for farm purposes valued at not more than 1,400 dols. each, and repairs therefor when entered at Customs after February 7, 1919. In order to expedite importation and delivery of the said traction engines and repairs therefor, they may be entered at the Custom House as free of ordinary duty and war tax on the usual form of entry for home consumption (B 1) until otherwise provided for.

INDUSTRIAL NOTES.

AT the close of the sitting on Tuesday, the 11th inst., of the Coal Commission, Mr. R. Guthrie, secretary of the Coal Owners' Association of Durham and Northumberland, said the average quantity of coal worked per hewer's shift was 4·23 tons in 1879. In 1915, the average was 3·5 tons; since then, there had been a further decline to 3·17 tons in 1918. In the latter year, during the whole of which wages were 107½ per cent. above the basis of 1879, the average earnings were 12*s.* 4·70*d.* per shift, exclusive of the war wage. It was not correct, he added, to say that wages were based on the figures of the worst collieries; they were based on the averages.

At the sitting of Wednesday, the 12th inst., a letter was put in from Professor Watkinson, of the University of Liverpool, stating that the weight of coal required per ton of finished steel was approximately 23 cwt., when the weight of coke required per ton of pig-iron was 16 cwt.

Mr. Finlay A. Gibson, secretary of the Monmouthshire and South Wales Coal Owners' Association, then produced a number of figures showing that the average wage per man per shift for the piece-work coal getters for the four weeks in June, 1914, excluding the amount paid by the coal-getter to any person on day wage, was 8*s.* 9·97*d.*, whilst in the four weeks in November, 1918, it was 16*s.* 11·99*d.* The average earnings per shift of other operatives, including boys, youths and women, was 6*s.* 5·64*d.* for the four weeks in June, 1914, and 12*s.* 5·28*d.* for the four weeks in November, 1918. For a total number of 1,731 pits covered by the estimates, the total gross output for the four weeks ended June, 1914, was 18,272,872 tons, whilst for the four weeks ended November, 1918, it was 14,694,920 tons.

Mr. Ralph Richardson, Barrow Hematite Steel Company, Limited, said if the miners' claim for a 30 per cent. advance on their present earnings and for a reduction of hours were conceded, the cost, exclusive of war wage, would be increased by a direct increase in the wages cost of 8*s.* 4*d.* per ton, an indirect increase in wages cost of 5·25*d.* per ton, an indirect increase in stores of 4*d.* per ton, an indirect increase in colliery consumption and workmen's coal of 6*d.* per ton, equal to a total increase of 9*s.* 7·25*d.* per ton. The reduction in hours might lead to a further increase of 1*s.* per ton. There might be, if the claims were granted, a slightly better attendance of the men, who would probably start work at 8 a.m. instead of at 6 a.m. Each increase of wages had in the past meant an increase in voluntary absenteeism. Returns from all the collieries in South Yorkshire showed the average time spent at the coal face to be 6 hours 45 minutes; if the reduction asked for took place, this time would be reduced to 4 hours 45 minutes. He estimated that the reduction in output involved by conceding the claim for a 6-hour day would be 29·8 per cent., and did not think there would be any compensating factor to diminish this reduction.

Mr. Wallace Thorneycroft, speaking on behalf of the Scotch coal owners, said a simple method for the Scotch miners to improve their standard of living would be by increasing their working days to the six which obtained in all other trades. Almost all the Scotch collieries were worked on the one-shift principle; there was one coal-drawing shift of 8 hours. He thought the 30 per cent. increase on present wages would mean an increase of 3*s.* 3*d.* in wages on the cost of raising each ton of coal. The effective working time at the face of coal getters was now 6 hours 45 minutes; if the same meal hours, from 30 minutes to 40 minutes, were taken, the substitution of "six" for "eight" in the Eight Hours Act, would be to reduce the effective working time at the face to 4 hours 45 minutes, a reduction of 29 per cent. The increase in wages and reduction in hours claimed would lead to an increase of 10*s.* 5*d.* in wages, of 1*s.* in timber and supplies and of 7*d.* for other charges, making 12*s.* in all. Moreover, to keep the pits going, and on a reduced output, there would be the following increase in the number of workmen—surface men 10 per cent. and underground men 5 per cent.

At Thursday's sitting of the Commission, Sir Richard Redmayne, reverting to his previous figures (see page 350 *ante*), said that corrections he was now able to effect in regard to Northumberland and Durham brought the reduction of output due to shorter hours to 19 per cent. instead of the figure he previously gave.

Mr. A. Lowes Dickinson put in a table showing a total of 454 collieries making a profit. Their output for two months was 25,832,645 tons, costing per ton 15*s.* 8*d.*, selling at 17*s.* 11*d.* per ton, showing a profit of 2*s.* 3*d.* per ton. The number of collieries working at a loss numbered 221. Their output for two months was 5,398,137 tons, costing per ton 20*s.* 4·2*d.*, selling at 18*s.* 3·9*d.* per ton, showing a loss of 2*s.* 0·3*d.* per ton.

Mr. Wallace Thorneycroft pointed out that coal miners were singularly free from tuberculosis and similar diseases, whilst the reverse applied to the tin mines of Cornwall owing to the prevalence there of siliceous dust.

Mr. Hugh Bramwell, South Wales, said that the effect on the cost of working for South Wales of the 30 per cent. increase would be 4*s.* per ton. The effect of substituting 6 hours for 8 hours was that the effective time, if the men did exactly as they did now, would be reduced by 31·6 per cent.; it would be reduced by 25 per cent. if the men expedited travelling and reduced their meal time. If the men worked as at present, the output would be reduced by 25 per cent.; if they exerted their estimated latent capacity, the reduction in output would be 20 per cent. The cost of working would be increased by 20 per cent., or by 5*s.* per ton, if aggravating factors were not allowed for; if these were allowed for, the cost of working would be increased by 25 per cent., equal to 6*s.* per ton. The cost of working due to increased number of day-wage men would be increased by 9*d.* per ton, making a total increase of 5*s.* 9*d.* or 6*s.* 9*d.* Adding to this the effect of the 30 per cent. increase in wages, or 4*s.*, he arrived at the extra cost of 9*s.* 9*d.* or 10*s.* 9*d.* He estimated that the directors fees in the coal trade was 1,000*l.* per 1,000,000 tons, or less than 1*d.* per ton.

Other witnesses dealt with the effect of the claims on the cost of Durham and Forest of Dean coal. Professor Henry Louis, Newcastle, in regard to the nationalisation of collieries, said that all the comparisons appeared to be unfavourable to State ownership. Wages were lower and coal prices higher in the State-owned collieries; the output per man was lower; profits were lower or non-existent; accidents and strikes were quite as frequent.

Mr. A. F. Pease expressed the opinion that State management would be of the gravest danger to the coal trade, to all other trades and to the nation as a whole. In regard to amalgamation of collieries throughout the country, that would be even worse, if anything, than State ownership. If collieries were owned by a huge combine, enterprise in every direction would be discouraged.

At the sitting of Friday, the 14th inst., Mr. A. Lowes Dickinson put in another table showing the profits of some and the losses of other collieries. He was followed by Mr. William Straker, secretary of the Northumberland Miners' Association, who said he found the capital invested in the coal-mining industry amounted to about 10*s.* per ton on one year's output; this was confirmed by Dr. Stamp, who gave this capital as 135,000,000*l.*, which equalled about 10*s.* per ton. Mr. Straker then referred to the profits alluded to by Mr. A. Lowes Dickinson (see page 349 *ante*). Working these profits out in proportion to output for each year, there was found an average profit during the war of 2*s.* 6·76*d.*, or 25·63 per cent. on capital invested. If the same rate of profits continued and the mines were purchased by the issue of coal mines stock to the present owners, carrying an interest equal to War Loan, 5 per cent., there would remain a profit of over 20 per cent., which meant that in five years the purchase price would be paid off out of profits. In addition, there were the royalties which ought to belong to the nation; the royalties were at present about 6½*d.* per ton, or over 5 per cent. on capital. There were also the profits on by-products. Royalties and by-product profits would add at least another 10 per cent. to the 25·63 per cent.

The Royal Commission on Coal Supplies had estimated that the loss of barrier coal had amounted to about 4,000,000,000 tons. These barriers were left between different coal properties as a division, to prevent collieries stealing each other's coal and also to prevent the water from one property flowing to the other, thus throwing the cost of pumping the whole of the water on the owner of one of the properties. There would be no necessity for this waste if the mines and minerals were nationalised.

The remainder of the sitting was devoted to the examination of a draft of provisions by the same witness, for a Mining Council, and to the question of housing.

A large part of the sitting of Saturday, the 15th inst., was also taken up by consideration of the housing question. Mr. John Robertson, chairman of the Scottish Union of Mine Workers, stated that the number of persons employed in and about the mines in the United Kingdom numbered fully 1,000,000. Going back for fifty years, there had been an average of 1,100 persons killed each year. In twenty years, the average of injured and off work for more than seven days each year was 160,000, or a total of about 3,250,000.

Mr. A. Lowes Dickinson then gave further revised figures. He now assumed that the average output per person employed in five pre-war years would prevail

in the near future, the figure being 257 tons. On this basis, and calculating the number of persons employed at, say, 1,100,000, the total output per annum would be 283,000,000 tons. The present cost, without increase of wages or decrease on hours, was 20*s.* 2*d.*

Thirty per cent. increase in wages, 45,000,000*l.*

Minimum reduced output owing to reduction in hours, say 10 per cent.

Resulting output for same number of men, 255,000,000 tons.

The cost would be 25*s.* 6*d.*

Increased cost due to both demands, per ton 5*s.* 4*d.* on 255,000,000 tons, equalling 68,000,000*l.*

This was divisible as follows: Wages increase 45,000,000*l.*, reduced hours 23,000,000*l.*

The estimated profits on present basis of hours and wages in excess of 1*s.* 6*d.* per ton, 3*s.* 2*d.* per ton, total 40,000,000*l.*

Deduct for fall in price of coal to neutrals 1*s.* per ton, equalling 12,000,000*l.*

Leaving 28,000,000*l.*, representing excess profits, to meet the miners' demands.

There was thus a deficit to be made up of 40,000,000*l.*

The last sitting of the Coal Commission for the taking of evidence was held on Monday, the 17th inst. Mr. Harper Parker, general secretary of the National Council of Mine Workers other than Miners, supported the men's demands. He said that the present wage in Lancashire, Cheshire and North Wales for winding enginemen was 12*s.* 10*d.* per day, inclusive of all war advances; boilermen and stokers received about 9*s.* 9*d.* per day; fan and ventilating enginemen and pump attendants 10*s.* per day. The winding enginemen had the most responsible work at the surface; they started at the age of 22 and remained at the work to an old age, some to 70 years of age. If the men's demand for shorter hours were granted, it would be necessary to employ more men to provide an extra shift where the present hours were 8 per day, and two extra shifts where the hours were 12 per day. The wages paid these men had never been commensurate with the value of their work. Other witnesses also gave evidence on behalf of the surface men.

Mr. A. E. Davies, general manager of the Banking Corporation, gave instances of colliery companies' profits, adding that the extent of these had in most cases been obscured by the capitalisation of reserves, or other readjustments of capital. The companies whose balance-sheet he reviewed, numbered two Welsh, two Scotch and two English companies, and he stated that he would consider 8 per cent. or 9 per cent. a fair dividend on capital, without any watering of the latter.

Mr. Charles Tennyson, assistant director of the Federation of British Industries, laid stress upon the increase in price of all commodities which would follow an increase in the cost of coal. After statements dealing with the status of claims of under managers, and with the profits of co-operative societies, Mr. Ernest Clark, Deputy-Chief Inspector of Taxes, Board of Inland Revenue, put in a large number of tabular statements showing total coal and by-product profits, royalties and wayleaves, profits on capital, &c., for the four years 1914 to 1917.

This concluded the evidence, since when the Commission has sat in private.

GOVERNMENT ORDERS.—*Charcoal Tin Plates.*—In reference to the Notice No. 28, dated January 24, 1919, the Minister of Munitions gives notice that the following shall be substituted for the extras therein quoted:—Tin per basis box: 3 lb., 3*s.* 9*d.*; 3¼ lb., 5*s.*; 4 lb., 6*s.* 3*d.*; 4¼ lb., 7*s.* 6*d.*; 5 lb., 9*s.* *Second-Hand Railway Wagons.*—In reference to the Railway Material (Second-hand) Order, 1916, dated December 29, 1916, the Minister of Munitions orders as follows: (1) The operation of the Railway Material (Second-hand) Order, 1916, is suspended until further notice in so far as relates to wagons of all types. (2) Such suspension shall not affect the previous operation of the said Order or the validity of any action taken thereunder, or the liability to any penalty or punishment in respect of any contravention or failure to comply with the said Order prior to such suspension or any proceeding or remedy in respect of such penalty or punishment. *Potassium Compounds: Kelp.*—In reference to the Potassium Compounds Order, 1917, dated October 17, 1917, the Minister of Munitions orders as follows: (1) The operation of the said Order is suspended on and after the 14th inst. until further notice, in so far as relates to kelp. (2) Same remarks as under (2) above. *Waste Paper.*—In reference to the Waste Paper (Dealings) Order, 1917, dated May 15, 1917, the Minister of Munitions orders as follows: (1) As from March 15, 1919, the said Order is hereby revoked. (2) Same remarks as under (2) above. *Bismuth Ores, Bismuth Metal and Products Therefrom.*—In reference to the Bismuth Order, 1918, dated March 12, 1918, the Bismuth (Amendment) Order, 1919, dated January 10, 1919, the Minister of Munitions orders as follows: (1) The operation of the said Orders is suspended on and after the 14th inst., until further notice. (2) Same remarks as under (2) above.

DIESEL ENGINE USERS' ASSOCIATION.

THE further list of additions to the membership of the Diesel Engine Users' Association announced at the meeting held this month is evidence of the increasing interest which is being taken in the general subject of oil as a fuel and in its use in engines of the Diesel and semi-Diesel types. The president, Mr. Napier Prentice, announced that at an early meeting a paper was to be read by Mr. Geoffrey Porter on the subject of "Engine Wear," which, in view of the trying conditions under which Diesel and semi-Diesel engines had continued working for some years during the war, should be of particular interest at the present time, and the discussion of which he thought would prove to be very useful and instructive.

Mr. C. T. Bullough had proposed to give some particulars and to state his experience in connection with his system of electrically heating tar-oil fuel, but his serious illness prevented him from attending, and it was proposed to circulate his notes on the subject among the members.

An interesting announcement was the formation of a French Association of Manufacturers and Users of Internal-Combustion Engines, and the suggestion that the two associations should co-operate in promoting the interests of users and manufacturers of heavy oil engines was cordially supported. It was also stated that the subject of the allowance for depreciation in connection with income-tax assessment purposes for Diesel and semi-Diesel engines was again receiving the attention of the committee.

A discussion took place on the "Definitions of Diesel and Semi-Diesel Engines" respectively. Draft definitions were submitted by Mr. Geoffrey Porter, with suggestions and proposed modifications by Messrs. James Richardson, A. Vincent Clarke, Napier Prentice and others. There was some criticism of the use of the term "semi-Diesel" as applied to hot bulb or hot surface ignition oil engines, but the general opinion expressed was that although the expression "semi-Diesel" might not be in every way desirable it was preferable to use a name which had now been some generally accepted, and which was well u and fairly simple, sooner than to use a more cr nomenclature which might be more strict As a result of the discussion, the follow were approved, and it was decided to circula among the members and subscribers before final adoption:—

Definition of a Diesel Engine.—A Diesel engine is a prime mover actuated by the gases resulting from the combustion of a liquid or pulverised fuel injected in a fine state of subdivision into the engine cylinder at or about the conclusion of a compression stroke. The heat generated by the compression to a high temperature of air within the cylinder is the sole means of igniting the charge. The combustion of the charge proceeds at, or approximately at, constant pressure.

Definition of a Semi-Diesel Engine.—A semi-Diesel engine is a prime mover actuated by the gases resulting from the combustion of a hydrocarbon oil. A charge of oil is injected in the form of a spray into a combustion space open to the cylinder of the engine at or about the time of maximum compression in the cylinder. The heat derived from an uncooled portion of the combustion chamber, together with the heat generated by the compression of air to a moderate temperature, ignites the charge. The combustion of the charge takes place at, or approximately at, constant volume.

INSECT PROBLEMS: ERRATUM.—In our article on "Insect Problems," on page 349 of last week's issue, reference was made to the report issued by the Commission on Westminster Hall in 1914. The report was presented by Mr. F. Baines, M.V.O.; we much regret that the name was misprinted, an "r" being substituted for the "i," and that the mistake was overlooked.

THE LATE SIR GEORGE LANCELOT EYLES.—We regret to have to announce the death, which occurred on the 12th inst., at the age of 70, of Sir George Lancelot Eyles, K.C.M.G., of the Croft, East Grinstead, and 12, Dean's Yard, Westminster. Sir George Eyles was associated for many years with the late Sir Charles Hutton Gregory, K.C.M.G., Past President of the Institution of Civil Engineers, and in 1892 he became his partner. Shortly after the death of Sir Charles Gregory in 1898, Sir George Eyles entered into partnership with Mr. F. J. Waring, C.M.G., late chief resident engineer to the Ceylon Government Railways. His firm had an extensive practice as civil and consulting engineers and acted in the latter capacity to the Crown Agents for the Colonies, for the Ceylon Government Railways, the Federated Malay States Railways, the Trinidad Government Railways, and the Nyasaland Railways. The firm were also engineers to the British North Borneo State Railway, the Central Africa Railway Company, and others, and until the creation of the Union of South Africa, Sir George Eyles acted as consulting engineer to the Agent-General for the Cape of Good Hope, for the Cape Government Railways. Sir George Eyles was a lieutenant-colonel in the Engineers Railway Staff Corps, he was created C.M.G. in 1902 and K.C.M.G. in 1914. During the Boer War he visited South Africa, was mentioned in despatches, and received the Queen's medal. Sir George Eyles was a prominent Freemason and acted as Grand Sword Bearer to the Grand Master, King Edward (then Prince of Wales), at the laying of the foundation stone of Christ's Hospital, Horsham. He was much esteemed in his profession, and his kindly and genial manner endeared him to a large circle of personal friends.

ROYAL METEOROLOGICAL SOCIETY.

THE usual March lecture of this Society was delivered on Wednesday, the 19th inst., at the rooms of the Geological Society, Burlington House, by Professor Leonard Hill, F.R.S., the subject being "*Atmospheric Conditions which Affect Health.*" The president of the Society, Sir Napier Shaw, F.R.S., was in the chair.

The lecturer first considered how far published meteorological data explained the influence of weather and climate on health and comfort, and in what way these data might be amplified to gain a better insight into this important matter. Numerous observers make records of barometric pressure, temperature, rainfall, wind, &c., but the question arises as to whether there are not other data of greater importance and interest, which affect personal health and comfort, and which might be recorded by them. Barometric pressure is measured with much refinement of accuracy, but we have no sensibility of the pressure of the atmosphere, which acts equally upon all parts of the body. In the past much has been made of the chemical alteration of the air in crowded places, and a false doctrine has become established and made popular. Careful analysis has shown that neither is there such a deficiency of oxygen or an excess of carbonic acid or other poisonous gas in the air of crowded rooms as to affect the health of human beings. Our feelings are largely due to swelling of the membrane of the nose and of its air sinus. The victims of the Black Hole of Calcutta died from heat stroke, not from a poisonous vitiation of the air by the exhalations of the crowd. It is the cooling and evaporative power of the atmosphere, and the radiant heat of the sun, or other source of radiant energy, which have a colossal effect on our comfort and well-being, and it is these factors which require to be measured by the student of hygiene. The dry-bulb temperature does not suffice to indicate the cooling effect, because it is a static instrument averaging the influence of the environment, while the body is a dynamic instrument keeping itself at a nearly constant body temperature by the internal combustion of food and by heat loss from the skin and respiratory membrane, the heat gain and loss both physiologically controlled. It is cooling power on the body surface, not temperature, which we o study, and as the surface of the respiratory e is always wet and the skin may be made dry or very wet by physiological control, e cooling is of no less importance than cooling by ction and radiation. To estimate cooling po rofessor Hill has introduced the kata-thermometer. This is a large-bulbed spirit thermometer graduated between 100 deg. and 95 deg. F., giving a mean temperature of 36·5 deg. C., which is arbitrarily taken as the surface temperature of the body. The instrument is heated in water at about 80 deg. C., until the meniscus enters the small bulb at the top of the stem; the rate of cooling from 100 deg. to 95 deg. F. is then measured in seconds. Three to five such measurements are made and the average taken gives the dry kata reading. The bulb is then covered with a wetted muslin glove, and the operation repeated. The average gives the wet-kata reading. Many thousands of kata observations have been taken in this country, also many in India, Egypt, Salonica front, Mesopotamia; also some in New York, Nigeria and Melbourne. These admit of a contrast between indoor and outdoor conditions, and the conclusion is reached by Professor Hill that the ordinary indoor conditions of this country approximate to outdoor conditions in such a humid tropical climate as Ceylon, admittedly an enervating climate to Europeans.

THE INDUSTRIAL RECONSTRUCTION COUNCIL.—A Conference on "The Place of the Merchant in British Industry," will be held under the auspices of the Industrial Reconstruction Council, on Tuesday, March 25, at 6 p.m., in the Hall of the Institute of Journalists, 2 and 4, Tudor-street, E.C. 4. The chair will be taken by Mr. W. Peter Rylands, of Messrs. Rylands Brothers, Limited, Warrington, and the opening address will be given by the Hon. F. M. B. Fisher. Questions and discussion will follow. No tickets are necessary.

H.M.S. "TRUANT."—Messrs. J. Samuel White and Co., Limited, East Cowes, Isle of Wight, delivered another ocean-going torpedo-boat destroyer to the Admiralty on Monday, the 17th inst. This valuable addition to the British Navy is the one hundred and seventeenth war vessel, the sixty-ninth torpedo vessel and the thirty-ninth destroyer constructed, engined and equipped by the firm, in addition to vessels of other kinds and innumerable small craft. The Truant was launched on September 18 last year, and is of 1,000 tons displacement and 28,000 shaft horse-power. Her propelling machinery consists of Brown–Curtis geared turbines built and fitted into the ship by the firm, and her boilers are oil-fired.

DOCK EQUIPMENT FOR SALE.—The Minister of Munitions announces that Mr. Alexander Bicket has been appointed Controller of the Dock Equipment and Plant Section of the Surplus Government Property Disposal Board. Mr. Bicket for many years has been associated at the Liverpool Docks with the handling and control of this class of material. The section will deal with the disposal of all dock and harbour equipment, cranes, transporters, elevators, &c., together with any other equipment and gear used in the handling of cargoes. At the present time a number of the above articles are available for disposal by private treaty, and all inquiries should be addressed to the Controller, as above, Room 715, Armament Buildings, S.W. 1, and should state as fully as possible the precise requirements of the applicant.

THE HARDENING OF STEEL.*

By Professor H. C. H. CARPENTER, F.R.S. (Royal School of Mines).

(*Concluded from page* 341.)

COMING now to the structures of pure γ iron, γ iron containing dissolved carbon, pure β iron, and pure α iron, the following facts have to be considered :—

Pure carbonless γ iron has never yet been obtained ; it is impossible by any quenching, however rapid, to bring down to the ordinary temperature the form of iron stable between A and G. The rate of change is too rapid. By means of either manganese or nickel, however, elements which lower the temperature of this transformation point below the ordinary temperature, it is possible to make alloys containing nothing but γ iron, and these possess a characteristic crystalline form ; they consist mainly of polyhedral crystals which exhibit a decided tendency to twin (Fig. 5)—that is, there are certain planes in each crystal about which the crystal elements tend to rotate through an angle of 180 deg., thus giving rise to the characteristic twin formation easily recognisable under the microscope. As already mentioned, between β and α iron, no difference in crystalline symmetry has been detected (Fig. 6). These irons also crystallise in polyhedral crystals, which, however, exhibit no tendency to twin. Structures of annealed steels are shown in Figs. 7 to 11.

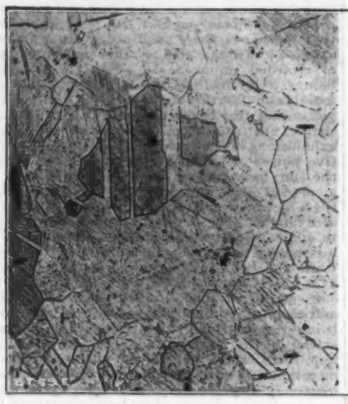


FIG. 5. γ IRON. × 80.

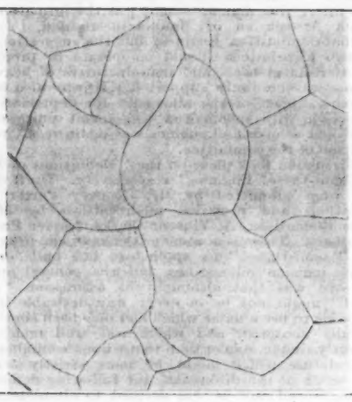


FIG. 6. α IRON. × 100.

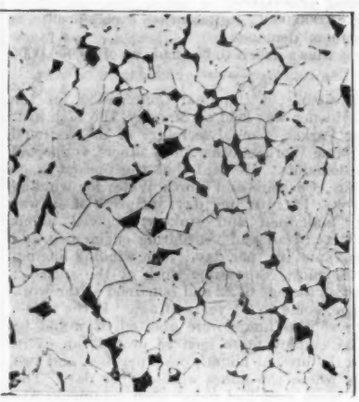


FIG. 7. 0.1 CARBON STEEL ANNEALED. × 120.

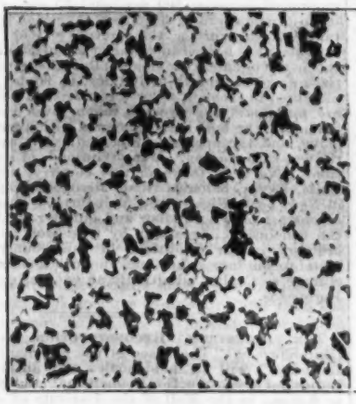


FIG. 8. 0.29 CARBON STEEL ANNEALED. × 120.

FIG. 9. 0.49 CARBON STEEL ANNEALED. × 400.

FIG. 10. 0.9 CARBON STEEL ANNEALED. × 120.

According to the equilibrium diagram, the solution of carbon in γ iron known as austenite must crystallise in the form of polyhedral crystals, since it is a solid solution, and these have the same general character as those of a pure metal. The structure of austenite, however, as obtained by quenching within the area of A G O S E, does not correspond to this theoretical deduction. Taking as an example the tool steel containing 0·9 per cent. C. If this is quenched, say, at 750 deg. C., a faintly marked acicular structure is obtained when the quenched specimen is examined. If the temperature of quenching be raised, this structure becomes more strongly marked and the needles are decidedly larger (Fig. 12), and even at the highest temperatures polyhedral crystals are never obtained. This acicular structure is known as martensite, and it is universally agreed that it is the characteristic structure of properly quenched steel. All the theories of the hardening of steel which have been put forward during the last forty years, centre round this one question, what is martensite ? If and when this question can be correctly answered it will furnish a complete answer to the question, why is steel hardened by quenching ?

Before considering these theories, two other facts must be briefly mentioned. Firstly, the carbide of iron which exists structurally free in an annealed tool steel, is a very hard substance, but as it is mixed with soft α iron in the proportion of 13·5 to 86·5, the tool is comparatively soft. This carbide can be separated from the steel by appropriate solvents which remove the iron. On the other hand, it is not possible to separate any carbide of iron from a properly quenched tool steel. When the latter is treated with dilute acids, the steel dissolves without residue and liberates a complicated mixture of hydrocarbons, both liquid and gaseous. There is therefore a fundamental difference in the form of the carbide in a quenched, as compared with an annealed, steel. In the former it is wholly dissolved, in the latter, wholly segregated. When a hardened tool steel is softened by annealing, the carbide of iron Fe_3C is gradually precipitated. If the annealing be carried out at low temperatures, it is precipitated in the form of ultra-microscopic particles which are known as troostite (Figs. 13 and 14). On raising the temperature the troostite passes into another variety known as sorbite (Fig. 15), and at still higher temperatures, well segregated pearlite results (Fig. 16). The gradual tempering and softening of hardened tool steel is caused by the precipitation of iron carbide in these forms, together with soft α iron, and as to this no difference of opinion exists.

Secondly, all tool steels, when properly quenched and thus hardened, are magnetic. As austenite is non-magnetic and as, so far as is known at present, the only form of iron which is magnetic is α, it follows logically that some α iron is present in hardened tools, and therefore that martensite is austenite which has undergone some change.

Up till recent times there were two chief theories of hardening, which were known as the allotropic and the carbonist. The former was mainly a French, the latter chiefly an English, theory. Whatever be the verdict of history on these two theories, there can be no question that each has been justified by the volume and character of the research work to which it has led. The two schools of thought were in many respects sharply opposed, but in the light of the fuller knowledge which exists to-day, it must be admitted that each has made a substantial contribution to scientific knowledge. The allotropic theory is in the main due to the late M. Osmond, who was the first to investigate the critical points of iron and steel by a delicate pyrometer. The history of the development of this theory is particularly interesting and must be briefly reviewed if a correct perspective of its merits is to be obtained. When M. Osmond first investigated the cooling of pure iron, he only detected the point Ar_3; as has been already mentioned, this is accompanied by a large evolution of heat. He called the iron above Ar_3 β ; that below it α ; and upon this he developed the following argument : There are two kinds of iron, the atoms of which are respectively arranged in the molecules so as to constitute soft and hard iron, quite apart from the presence or absence of carbon ; in red-hot iron the mass may be soft, but the molecules are hard, let this be called β iron ; cool such red-hot pure iron, whether quickly or slowly, and it becomes soft ; it passes to the α modification because there is nothing to prevent its doing so. If, however, carbon is present and the steel be rapidly chilled, the following result is obtained—a certain proportion of the molecules are retained in the form in which they existed at a high temperature, namely, the β modification which is hard, and hard steel is the result. According to this view, then, the hardness of quenched steel is due directly to iron and only indirectly to carbon.

Subsequently, when M. Osmond had perfected a more refined method of taking cooling curves, he discovered the critical point at Ar_2 ; as already mentioned, the evolution of heat is very much less than at Ar_3, and for some time he was unable to decide whether Ar_2 was merely the termination of Ar_3 spread over more than 100 deg., or was an independent point. Finally, when he had shown that at Ar_2 magnetic properties appear in the iron, he decided that this point was independent of Ar_3. The logical consequence of this was that three varieties of iron had to be considered. Now comes the important point—M. Osmond changed his theory of hardening, and put forward the view that it was not the iron above Ar_3 which was hard, but the variety which existed between Ar_3 and Ar_2 ; the iron above Ar_3 was called γ, that between Ar_3 and Ar_2 β, and below Ar_2 α.

The difference between the two theories will now be obvious. Whereas in the former the hard form of iron was that which existed in what we know to be the γ region, in the latter it was the variety which existed in the narrow temperature range between Ar_3 and Ar_2. Hardening was thus due to an intermediate form of iron between the varieties stable at high and low temperatures. According to the new theory β iron was still supposed to be the cause of hardness, but the new β was quite different from the old one, and progress in the

* Discourse delivered at the Royal Institution, on Friday, March 7, 1919.

development of the theories of hardening would have been more rapid if it had been generally realised that the original hard β iron was, according to the more accurate knowledge revealed by later work, γ iron.

The new theory presupposed the existence of all three forms of iron in a quenched tool, and according to it, the act of quenching permitted the retention of only a portion of the γ iron, while the remainder was converted into a mixture of β and α, the former conferring hardness of quenched tool steel was supposed to be due to a crystalline variety of iron, namely β, intermediate between γ and α.

According to these theories then, the special constituent present in quenched steel, namely martensite is due to β iron. It is possible to test this theory to-day by fuller knowledge, and it will be sufficient to advance two considerations which seriously invalidate it. In the first place, if the equilibrium diagram be examined, diagram had been well established before M. Osmond advanced his theory. The fact is, however, that when the allotropic theory was put forward, knowledge of the diagram was very far from being as complete as it is to-day.

In the second place, this theory can be tested by experimental work published nearly six years ago by Messrs. Rosenhain and Humfrey.* These investigators carried out a research on the tenacity of mild steel

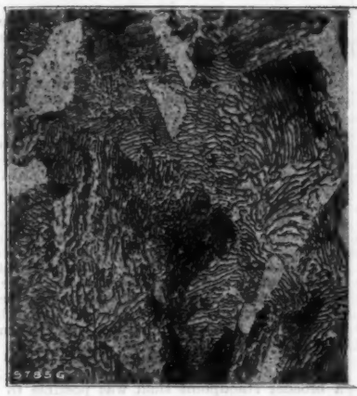


FIG. 11. 0.9 CARBON STEEL ANNEALED. × 400.

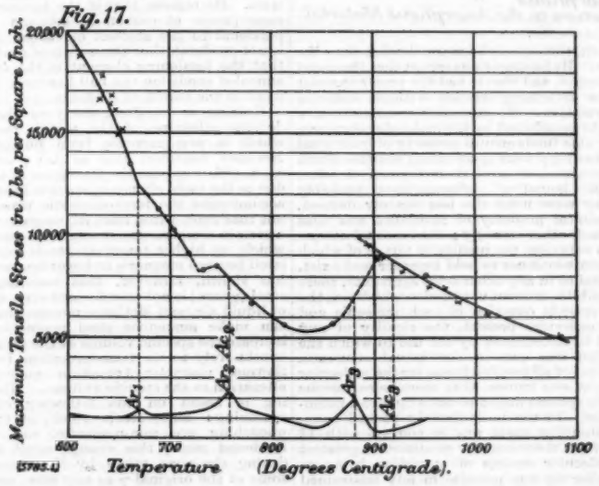
FIG. 12. 0.9 CARBON STEEL QUENCHED AT 1100 DEG. C. × 400.

FIG. 13. FIRST APPEARANCE OF TROOSTITE (BLACK). × 120.

FIG. 14. FURTHER DEVELOPMENT OF TROOSTITE (BLACK). × 120.

FIG. 15. SORBITE. × 120.

FIG. 16. PEARLITE, WITH TRACES OF SORBITE. × 120.



the hardness, and the latter the toughness and magnetic properties.

This theory was enthusiastically adopted by many workers, though certain modifications of it were put forward from time to time. Whereas the Osmond theory predicated that the β iron separated in a carbonless form, the whole of the carbon being retained in the γ iron, one of the modifications put forward, was that the β iron contained some dissolved carbon. The theories, however, all had this in common, that the it will be seen that in the case of all tool steels—that is those containing from 0·7 per cent. to 1·5 per cent. carbon—γ iron passes directly to α and not by way of β iron at all, and it is difficult, though not impossible, to see why β iron should be formed. The usual answer made to this objection is that the diagram refers only to the stable varieties of steel, and that during quenching, fugitive and unstable varieties are formed, one of which may be β iron. I cannot help thinking that this answer would never have been thought of, if the equilibrium

In the second place, this theory can be tested by experimental work published nearly six years ago by Messrs. Rosenhain and Humfrey.* These investigators carried out a research on the tenacity of mild steel containing 0·1 per cent. carbon between 1,080 deg. and 612 deg. C. This material contained therefore α, β, and γ iron. Strictly speaking, their research does not test hardness in the ordinarily accepted sense of the term, but it cannot be denied that determinations of tenacity do test the cohesion of a material which may be properly regarded as intimately connected with hardness. The authors found what they describe as two very well marked discontinuities in the temperature-tenacity curve (Fig. 17), corresponding to the critical points A_3 and A_2, but whereas the discontinuity at A_3 was large, that at A_2 was quite small, and their results must be regarded as negativing the view that β iron is harder than γ iron; in fact, if their curve be examined it will be found that the iron has a decidedly greater tenacity just above Ar_3 than just below it, even though a decrease in tenacity would be expected owing to the higher temperature. At 950 deg. C., where their iron was in the γ range, the tenacity was markedly greater than at 850 deg. C., where it was in the β range. It is very interesting that these results of Rosenhain and Humfrey, fit in better with the original theory of Osmond, which was really a γ iron theory, than with the later one.

It must also be regarded as improbable that beta and alpha iron, which, apart from the fact that the former is non-magnetic and the latter magnetic, only exhibit slight differences in properties and in particular between whose crystalline forms no difference has yet been discovered, should differ so strikingly in one particular property—hardness—such as is demanded by the above theory. From the work of Sir George Beilby, which will be subsequently quoted, it would appear that two varieties of a metal possessing the same crystalline form would be likely to have the same hardness.

The carbonist theory of hardening, as the name implies, throws the chief, in fact the sole emphasis, on the function of carbon. It owes its inception to the pioneering work of Sorby, of Sheffield, who made a very careful study

* Journal of the Iron and Steel Institute, No. I, 1913, pages 219 to 268.

of the microstructures of quenched and annealed steels. On this view the hardness of quenched steel is to be ascribed to the conversion of the pearlite, stable below Ar_1, into an amorphous constituent called hardenite, which corresponds empirically to the formula $Fe_{24}C$. According to the views of later carbonists, this hardness is the property of this solid solution which is stated to be amorphous, and, the whole of the carbon is regarded as having been trapped by quenching and retained in solid solution.

Modern research has shown that this theory is right in its assumption that the whole of the carbon is dissolved, in a properly quenched steel, but in their desire to disprove the allotropic theory of hardening, the exponents of this theory have gone to the unwise extreme of denying that the allotropic forms of iron have any influence on the hardness of tool steel at all. When it is remembered that iron carbide is practically insoluble in α or β iron, but is only soluble in γ iron, it is certainly unscientific to deny that that γ iron has any share in the hardening process. Moreover, the theory as stated in the above form is both incomplete and contradicted by certainly one fact. It is not correct to say that the constituent formed on quenching a tool steel above A_1, is amorphous, if by that is meant that it is wholly amorphous; the structure of a quenched tool steel is in the main crystalline, although, as will be subsequently suggested, some amorphous material may be present. The carbonist theory does not explain the martenistic structure of a quenched tool. If there was nothing more in the hardening process than is contained in the carbonist theory, the structure of a quenched steel should consist of polyhedral crystals, because this is the typical structure of a solid solution. Further, the hardness of quenched steel is much greater than that which can be explained merely by the retention of iron carbide in iron. Some other factor must enter in. Finally, the fact established by McCance, that on adding carbon to iron, the hardness of the quenched steels increases up to 0·7 per cent. carbon, and remains constant between this point and 1·18 per cent., receives no explanation from the carbonist theory, and appears to point to the conclusion which McCance has already drawn, that, at any rate, some of the hardening must be due to the iron itself, and that there is a definite limit to the amount of hardening that iron can stand. These two theories mainly held the field for the best part of twenty years, and anyone who reads the history of this stimulating period in the development of metallographical thought, cannot, I think, avoid the conclusion that the allotropists made a serious mistake in laying such exclusive emphasis on the function of iron, while the carbonists made an equally serious mistake by denying that iron had anything to do with hardening at all.

I pass now to consider some important research work, which, although it was not carried out on iron or steel, or indeed, any other alloy of iron, has nevertheless profoundly influenced the views of metallographers with regard to the causes of the hardening of steel by quenching. This is but one instance of many which the history of scientific discovery provides, that the great advances in any particular field of knowledge, are not as a rule due to workers in that particular field, but to those whose labours apparently have little direct relation to them. In this case I refer to the researches of Sir George Beilby on the hard and soft states in metals. These researches were carried out on metals which could be obtained in a very high degree of purity, and which did not possess, so far as is known, any critical points, such as those that characterise the metal iron.

The experiments were carried out for the most part with gold, silver and copper, and there is no doubt that he made a wise choice in selecting these particular materials, because they are most suitable for the particular study which he had in view. His early researches were concerned with the microscopic study of the structure and behaviour of thin films of metal, and this led him to the discovery of the nature of the operation of polishing, &c. He found that in this operation, a true skin is formed over the polished surface, and that this gives unmistakable signs that it has passed through a state in which it must have possessed the perfect mobility of a liquid, although the operations were carried out at the ordinary temperature, which is several hundred degrees below the melting points of the metals in question. (Fig. 18 shows this diagrammatically for calcite.)

The metal itself in the annealed condition is composed of crystals, but the skin formed by grinding and polishing, possesses distinctive qualities which differentiate its substance very clearly from that of the unaltered substance beneath it. It is, for instance, much harder, and even when formed on the face of a crystal on which the hardness varies in different directions, its hardness is the same in all directions. Since the skin can be dissolved off in stages, it was possible thus to gain an insight into the history of its formation. The surface skin can thus be investigated analytically as well as synthetically; it can be built up in stages by polishing, and it can equally easily be removed in stages; the latter operation having the advantage over the former that the method of solution lends itself to a step by step removal of great refinement and accuracy. The discovery that layers of a solid many hundreds of molecules in thickness can have the mobility of the liquid state conferred upon them by purely mechanical movement, opened up a new field of inquiry into the internal structure of metals which have been hardened by cold working. As a result of this inquiry, Sir George Beilby put forward a theory of the hard and soft states of metals, according to which hardening results from the formation at all the internal surfaces of slip or shear, of mobile layers similar to those produced on the outer surface by polishing. These layers only retain their mobility for a very brief period, and then solidify in a vitreous amorphous state, thus forming a cementing material at all surfaces of slip or shear throughout the mass. The keystone of the theory is thus the instantaneous liquefaction followed by the solidification of sheets of molecules during mechanical deformation (Fig. 19).

It was never found possible even by the severest deformation, to convert a crystalline into a completely amorphous metal. The resulting product was always a complex of the two varieties. In using the expression "amorphous," Sir George Beilby was careful to explain that amorphous meant non-crystalline, in the sense that the molecules are not marshalled in crystalline order and orientation, while the addition of the qualifying term vitreous, narrowed the field to substances which in some degree resemble the glasslike form assumed by the silicates on cooling from the molten state. Glass is a typical amorphous substance, the useful qualities of which depend entirely on the fact that it is in the non-crystalline state; as is well known, it is a very hard substance.

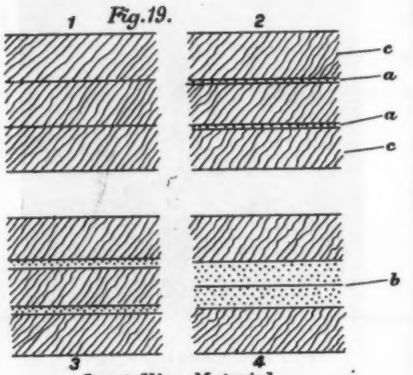
By careful experiments, Sir George Beilby was able to show that the amorphous constituent formed by cold work is not thermally stable, but that on annealing, it reverts at a given temperature to the crystalline state. Well-marked differences of properties, according to whether the metal was wholly crystalline or a complex of vitreous-amorphous and crystalline units, were established. Thus, the crystalline phase of a given metal was shown to be thermally stable but mechanically unstable, whereas the amorphous phase was mechanically stable and thermally unstable.

Subsequently, in the discussion on a paper by Professor Edwards and myself, Sir George Beilby explained why*

Fig. 18.

Black Area represents Flawed (Amorphous) Material.
White " " unaltered Calcite.
(3765.L)

Fig. 19.



c — Crystalline Material
a — Amorphous "
b — Fracture in the Amorphous Material.
(3765.N)

in his view the vitreous-amorphous was harder than the crystalline phase. By hardness was meant that the metal was more or less rigid, and that it had the power to resist larger or smaller deforming stresses without suffering permanent deformation. He proceeded to consider how this rigidity might be affected by the molecular structure of the metal. "One fundamental property of individual molecules was that they were space-filling entities which resisted the encroachment into their domain of other molecules; their bounding surfaces were probably kinetic, but they were none the less sharply defined. Another fundamental property of molecules was that they attracted each other strongly; that mutual attraction gave rise to cohesion, the quality in virtue of which the physical world continues to hold together and exist. In a mass of metal or in any other solid aggregate, there was a certain available amount of cohesion which was the product of the specific cohesion of each molecule and the number of molecules present, the rigidity of any aggregate would be determined by the use to which the available cohesion was put in the actual structure. Taking the simplest of all possible forms for the molecular unit, the sphere, it was known, that there were various ways in which the spheres might be built up into a homogeneous structure. In the most densely packed form, each sphere within the mass was in contact with 12 others; in that form there was the condition of greatest rigidity, the molecular centres of attraction being as close to each other as was possible in any unstrained structure. But close packing of that form was not by any means common in crystal structures, indeed, it was not quite certain that it existed at all; it certainly did not by any means represent the inevitable completion of crystalline effort; in the crystal therefore, the structure was not necessarily or even probably the most rigid possible structure. The available supply of internal cohesion was not all used up to secure maximum rigidity. In the less closely-packed assemblages of spheres it could be imagined that by a small translation of the layers of molecules relatively to each other, a more rigid structure might be produced. If, for example, in an assemblage of spheres in which each was only in contact with six others, a displacement occurred which brought each into contact with 12 others, it was clear that the new structure would be at least twice as rigid as the original structure . . . It was believed that in the metals which crystallised in the regular system, such as gold, silver, copper, iron, &c., the molecules were not in closest packing; in these metals, the crystalline state was one of great mechanical instability, and consequently of very small rigidity; as a result of that, disturbances by deformation caused very widespread breaking down of the crystal structure with momentary liquefaction of molecular layers and groups. If that occurred at a point below the crystallisation temperature the newly solidified portions could not receive their crystalline arrangement, and remained chilled or frozen into a more rigid type of structure, a type in which the available cohesion of the mass was more fully utilised than in the crystalline state . . . In the case of ductile metals flow under deforming stresses followed by resolidification left a proportion of the molecules in a condition of constraint, their freedom as vibrating units being impaired . . . If, then, the available cohesion of the mass could in that way be so effectively utilised that it could put a constraint on the vibration of the individual molecules, it was not at all surprising that the molecules were so much more closely held by each other, that a greater force was then required to move them over each other under deforming stresses."

In the light of investigations such as the foregoing, the hardening of steel by quenching can be viewed from a broader standpoint than was possible to earlier researchers. We know to-day that metals may be hardened in four distinct ways: (1) Pure ductile metals can be hardened by cold work; (2) these metals may be hardened by being alloyed with one another, or with certain non-metallic elements such as hydrogen, nitrogen, carbon, &c.; (3) if these mixtures are ductile, they may be further hardened by cold working, for instance a brass (70 copper, 30 zinc); (4) certain of these alloys can be hardened by chilling. The hardening of steel by quenching comes in this class. It is important to remember that the rapid drop in temperature, which quenching produces, may act in two ways: (a) "It may stereotype the form of chemical combination or of structure, crystalline or non-crystalline, which is in the condition of equilibrium at the temperature at which chilling begins; (b) it may set up contraction strains within the cooled mass; these strains may be wholly or in part either within or beyond the elastic limits. When the strains exceed the elastic limit, and permanent deformation occurs, then hardening may result as in (3)."*

One other fact must still be mentioned. Charpy and Grenet have shown that in iron containing very small amounts of carbon, an expansion occurs on passing the Ar_3 point, that is from γ to β iron; and further that in steels of tool steel composition the separation of iron carbide from austenite on cooling is also associated with an expansion.

I pass now to consider three of the most modern theories of hardening; two of these were enunciated simultaneously and independently in May, 1914; the third in November of the same year. The first of these is due to Dr. McCance. As already mentioned, he showed that when the carbon reaches about 0·7 per cent. a maximum hardness is obtained in the quenched state, and this value is not exceeded in any pure carbon steel. He reasons that if the hardness were the direct consequence of carbon in solution it would be proportional to the amount of carbon dissolved; that it is not so shows that the action of carbon is indirect and that the hardening element is the iron itself. In the annealed condition the ball hardness of this steel is 174, while in the hardened condition it is 713.

Holding as he does, the view that β iron is not a definite allotrope of the metal, but merely α iron which is non-magnetic from purely thermal causes, McCance considers that at Ar_3 γ iron passes directly to α. He explains the liberation of heat at A_2 as being due to the rapid change in specific heat which necessarily accompanies the ferro-magnetic transition. He points out that since α iron loses its magnetic properties above a certain temperature, it might be suggested that γ iron, which, at higher temperatures is non-magnetic, might itself become magnetic at lower temperatures. Hadfield has shown, however, that non-magnetic manganese steel (γ iron) is not transformed even at the temperature of liquid air, and McCance reasons that as no treatment can make austenitic steel magnetic which does not increase the specific volume at the same time, this points conclusively to its transformation to α iron, since the thermal magnetic transition makes no appreciable alteration in the specific volume. His theory of hardening is based on the following considerations and reasoning: Since steels which, at the temperature of quenching are non-magnetic, are magnetic in the hardened state, this change must have taken place during the time taken by the quenching; therefore some of the original γ at any rate, must have changed to the magnetic α condition. Measurements of the electrical resistance, however, show that the carbon still remains in solution, therefore under the conditions of quenching, the transformation of the iron from the γ to the α state, can take place independently of the change in the state of the carbon from one of solution to that of precipitation. Thus, these two transformations, which on slow heating and cooling take place

* Journal of the Iron and Steel Institute, No. I, 1914, pages 178 to 180.

* Transactions of the Faraday Society, Beilby, November, 1914.

simultaneously, can behave as independent reactions, although in a limited sense. "For, though martensite may be considered as an enforced solution of carbon in α iron, it must not be forgotten that there is still some γ iron present with the carbon, which is absolutely necessary to maintain its solubility, and any change in the state of the carbon causes this transformation of γ iron to α. It might be on this account, he suggested, that the iron is chemically combined with the carbon, but an examination of the curve connecting the loss of magnetic saturation intensity with the carbon content shows that the γ iron increases much more rapidly than the amount of carbon, which points to purely physical influences."* McCance then considers the cooling of a hypoeutectoid steel, that is, one containing rather less than 0·9 per cent. carbon. As he points out, its complete transformation into iron and cementite, involves two distinct transformations: (*a*) A change in the state of the iron from γ to α; (*b*) a change in the state of the carbon. The first of these can take place independently of the second, but when the second takes place it necessarily involves the first. There are therefore three possible conditions:—

1. Both transformations are completed, producing pearlitic steel which is soft.

2. Both transformations are suppressed. This has never been achieved with any pure iron carbon alloy, and the addition of a certain amount of manganese is necessary as Maurer has shown. In this case pure austenite results, and this, while harder than the steel in the pearlitic condition, is nevertheless softer than a hardened steel.

3. When (*a*) takes place, but (*b*) is suppressed, then the resulting structure is martensitic, and according to McCance's theory, the α iron formed under this condition is interstrained and very hard. Case 3 then is the important one from the hardening standpoint, and to be possible, it is necessary that a difference should exist in the respective velocities of transformation of (*a*) and (*b*), so that with an appropriate rate of cooling, the slower transformation can be suppressed, while the faster still takes place. On McCance's view, then, it is interstrained α iron, which is the cause of the hardening of steel. He does not, however, accept Beilby's theory of a hard vitreous amorphous phase. His view of interstrain is as follows: "Metals in their normal unstrained condition are crystalline, that is, they are composed of an orderly arrangement of their constituent atoms arranged in a space-lattice which conforms with whatever symmetry the crystals possess. Successful attempts have been recently made by the aid of X-rays to determine the actual position occupied by the atoms, and copper, for instance, has been shown to have its atoms built up in a "face-centred" cube, that is a cube having an atom at each corner, and one at the centre of each face. The effect of deformation on such systems must be to alter the position of each atom relatively to its neighbour, and permanent deformation must cause so much alteration that the atoms along the planes of slip can no longer return to their positions of equilibrium. This corresponds to the condition of interstrain and results in a hardening of the material."† McCance admits that the destruction of the crystalline arrangement does go so far as to render the material in these planes of greatest movement, actually amorphous but appears to deny that this amorphous phase is hard.

The important connection between rate of cooling and hardening is well illustrated by the behaviour of alloy steels. If, for instance, manganese is added to the steel it lowers the temperature of the transformations and greatly decreases their velocities, so that, with sufficient manganese, even at ordinary rates of cooling, the structure is martensitic, and the steel very hard and brittle. The addition of even more manganese ultimately prevents any transformation taking place, even when the steel has cooled to the ordinary temperature, and a pure austenitic steel is the result. If the martensitic manganese steel be water-quenched not only is it not hardened, but it is actually softened, this being due to the complete suppression of both transformations and resulting in the production of an austenitic steel. Similar results may also be obtained with nickel.

The following experiments quoted by McCance are also important as bearing out his contention that the main causes of the hardening of steel lies in a change in the iron itself. A steel containing 3·6 per cent. nickel and 0·19 per cent. carbon had a normal hardness of 183, which, on quenching in water from 1,000 deg. C., had risen to 444, whereas a steel containing the same amount of carbon, but no nickel, increased after the same treatment from 143 to 218. In other words, whereas the carbon steel increased only 75 points, the nickel steel was augmented by 261. As nickel does not form a carbide in this range of composition, the state of the carbon is similar in both alloys, consequently the increased hardness must be due to the influence of the nickel on the iron, and McCance explains this by the view that the iron is enabled to retain a greater degree of interstrain by lowering the temperature at which the transformation of γ to α iron takes place. He rightly lays stress on the importance of internal friction in retarding transformations and preserving metastable states.

McCance's theory of hardening has been built up by acute reasoning on a solid foundation of well-established facts. As yet, however, it cannot be regarded as constituting a complete theory, because it is intentionally non-committal with regard to the expression "interstrain." As he points out, the theory of interstrain action is in itself an inquiry, and that inquiry has yet to be undertaken.

* Transactions of the Faraday Society, 1914, page 56.
† Transactions of the Faraday Society, 1914, page 53.

The second of the most modern theories of hardening was put forward by Professor Edwards and myself.* We started from the position that steels are not the only alloys which can be hardened by quenching in water from moderately high temperature. Many alloys, in fact, are known which possess this property. The difference is one of degree and not of kind. Steels, in fact, are simply the higher members of a group of different alloys which possess the same characteristics in varying degrees. Further, all the alloys which behave in this way have similar constitutions at high temperatures, and undergo precisely similar changes as they cool to atmospheric temperature. They undergo decomposition at certain critical temperatures which are marked by evolutions of heat. It is generally admitted that the hardening produced by quenching any of these alloys is in some way related to the effect of quick cooling upon these critical heat changes. Within certain limits the effect of varying the rates of cooling upon the A I change in steels, and other similar changes, is well known. As the rate of cooling is increased, the temperature at which the changes occur is progressively lowered and simultaneously the thermal magnitude is decreased. It is therefore in agreement with established facts to say that, as the rate of cooling is increased, there is an increased tendency to prevent the critical change taking place, and to keep the heat of the change suppressed. The careful experiments of Professor Benedicks show that when the highest quenching velocities are attained, there are no indications of any heat at all being evolved. Logically, therefore, these facts appear to point to the view that the hardening is connected with the suppression of the heat of the inversion. If this be the case, energy has to be brought to bear upon the specimen during the quenching process in order to overcome the tendency for the inversion to take place. This energy is considered to be brought to bear in two ways:—

1. By the sudden contraction of the outer shell or envelope of the specimen.

2. By an internal molecular contraction of the mass which is connected with the solution or osmotic pressure of the dissolved carbon in the case of steel.

This explanation, so far as it goes, is a perfectly general one, applicable to all alloys which may be hardened by quenching.

The next step in the argument is as follows: In the case of all alloys hardened in this way, when the heat change is suppressed, severe internal stresses are set up, which exceed the elastic limit, and consequently cause an internal straining of the material; that, in the case of steels, the metal is internally strained, appears to us well established. According to the view put forward by us in 1914, martensite is simply twinned austenite produced by this internal movement, and, further, along the twinning and gliding planes amorphous material is produced by the distortion of the crystalline units, which material we regard as corresponding to Beilby's hard vitreous-amorphous phase produced by mechanical work. In order to establish this theory, therefore, evidence should be produced that these actions take place. For such evidence in full, the original paper must be consulted, and only the briefest *resume* can be given here. The view that internal straining occurs during the quenching of steel has only been challenged by one authority, Dr. Rosenhain, who says "this view meets with the insuperable difficulty that although quenching does set up severe stresses in steels, it does not cause any serious flow or movement; the strain hardening of metals only becomes marked when severe plastic flow has occurred." This objection, however, breaks down on examination. It is true that in cold-working a metal, a large degree of strain is needed to produce great hardness, but in this case the direction of strain is constant throughout the mass, so that the strains are additive, and these result in a great change of outer dimensions. But the strains in the slipping planes set up by hardening from quenching are quite different. They are not in constant, but in opposite, directions along different internal planes, and they therefore offset each other and do not deform the mass as a whole. That severe straining does occur, therefore, may be accepted as established. The microscopic evidence for this straining was regarded by us in our original paper as being due to a great development of twins in the steel. It was pointed out, however, in the discussion that although twinning might have occurred, this would not necessarily cause any increase in hardness, since the two halves of every twin should dovetail perfectly into each other, and therefore amorphous material need not necessarily be produced in the twinning planes. This may be so, but for the purpose of this theory it does not matter whether the movement is regarded as taking place along twinning or along slip planes; in the latter case it is generally agreed that amorphous material must result by the distortion of the crystalline units. According to this view, then, martensite is austenite which has been distorted by the formation of amorphous films along the slip planes of γ iron. It will be observed that I have already begun to use Sir George Beilby's theory of the hard amorphous state in order to explain the hardening of steel by quenching, by suggesting that amorphous material is formed along the slip planes of γ iron. What is now required is to show, if possible, that these layers persist on quick cooling. Beilby has shown that when strain-hardened metals are heated, the amorphous layers re-crystallise and the actual temperature at which this occurs varies with the particular metal and with the degree of strain hardening. Accordingly, if, in quenching, the rate of cooling is sufficiently quick, the temperature of the mass will be lowered below that at which re-crystallisation occurs. In the case of pure iron it has been shown by Chappell and Goerens that the minimum temperature for the strain hardening of iron is about 500 deg. C. It is quite certain that the minimum temperature for a steel containing 0·9 per cent. carbon will be higher than this. How much is not known, but let the figure 500 deg. C. stand for this particular steel. In hardening the steel is quenched from a temperature which should not be higher than 800 deg. C. The important interval, therefore, in the quenching operation is between 800 deg. and 500 deg. C. In one of Benedicks' experiments, to which reference has been already made, the time taken to pass through this interval was exactly 1 second; in the case of a tool of about 1 in. diameter it will take longer for the centre to pass through this interval, but the probability is that it will not take more than 2 seconds to 3 seconds for the skin of the tool to pass through this interval. In such a case, therefore, our view is that the vitreous-amorphous layers formed will certainly not have time to re-crystallise, but will be preserved and hardening will result. It would follow, then, that the final cause of hardening by quenching is exactly the same as that of hardening by cold working. In the case of tool steels and other alloys of a similar nature, the actual stresses which are set up in quenching, which give rise to the twinning or slipping, are brought into action only in the very brief period during which the mass is cooling; therefore, while the metal is undergoing intercrystalline slip and the amorphous layers are being formed, the chances for these to recrystallise become less and less as the cooling proceeds; indeed, it may be that a large proportion of the slipping which occurs takes place at moderately low temperatures below that at which the amorphous layers are able to re-crystallise. Put briefly, then, our theory of the hardening of steel is—that it is due to the formation of hard vitreous-amorphous films of a solution of carbide in γ iron formed along the slipping planes of the austenite.

So far as I am aware, there is only one property of quenched steels which is not accounted for by this theory, namely, that all quenched steels are magnetic. It has not been shown that amorphous γ iron is not magnetic, though it is not at all probable, since the property of magnetism is almost certainly associated with a definite orientation of the molecules in iron and steel. Admitting, as may be done on present evidence, that ferro-magnetism is a property of α iron, our theory can be brought into harmony with the fact that all quenched steels are magnetic, by adopting McCance's view that some γ iron passes to α in the quenching of all steels.

The third modern theory of hardening to which I wish to allude was put forward some six months after the two theories which have been briefly outlined. It is due to Mr. J. C. Humfrey.* This theory rests upon the assumption that a hard amorphous phase is responsible for the hardness of quenched steel, and in this respect resembles the theory put forward by Professor Edwards and myself. The formation of this phase, however, is attributed to entirely different considerations, which will now be briefly set forth. Mr. Humfrey considers in the first place what happens when one allotropic form of an element passes into another. He starts from the theory of crystal structure already alluded to in McCance's theory, namely, that the centres of gravity of the molecules are arranged together according to one of a series of geometrical devices, called space-lattices. In each molecule of such a crystal the atoms are similarly situated.

When an allotropic change occurs in such a crystalline body, there is an internal rearrangement of the atoms in each molecule, and if the new form which the molecules take involves a corresponding change in the external forces which they exert upon one another, the space-lattice may become unstable and a different one formed. Before, however, the reorganisation can be completed, it is assumed that there must be temporarily a state of disorder, and it is during this period that Humfrey considers that the structure must be considered as amorphous. This intermediate state is regarded as corresponding to the liquid "which would be formed by the fusion of the solid phase stable at the lower temperatures, if the conditions could be so adjusted that the subsequent recrystallisation were avoided."

The temperature-tenacity curves obtained by Rosenhain and Humfrey are regarded as indicating that the melting-points of α and β iron would be considerably lower than that of γ iron, if they could be preserved unchanged up to their melting-points. In the next place consideration is given to the fact that physical changes of state do not take place instantaneously throughout the whole mass of any given substance, but that they start from certain nuclei and proceed outwards. From this Humfrey conceives that the intermediate amorphous phase existing during an allotropic phase, begins to recrystallise almost as soon as it is formed, "and is present at any particular instant during the change, merely as thin films or layers between the co-existing crystalline phases, the films moving forward as the change progresses. The course of the breakdown of the one crystalline phase to the amorphous would tend to follow those planes in which the freedom of movement was greatest, namely, the crystal-gliding planes and possibly the intercrystalline boundaries."

With regard to the formation of a new crystalline phase, Humfrey points out that the temperature at which it occurs must not be too low for the forces of crystallisation to overcome the viscosity of the amorphous phase. If the viscosity is sufficient to prevent recrystallisation, the amorphous phase formed will be practically stable. Even in cases, however, where an allotropic change normally takes place at a temperature well above that

* Journal of the Iron and Steel Institute, No. 1, 1914, pages 138 to 177.

* Transactions of the Faraday Society, 1914, pages 35 to 43.

at which the viscosity is sufficient to prevent recrystallisation, abnormal conditions such as rapid cooling may delay the change to well below this temperature. He then applies these general considerations to the case of steel. γ iron normally inverts to β iron at about 900 deg. C. The recrystallisation of work-hardened α iron is very slow below 500 deg. C. This gives an interval of 400 deg. In the case of the 0·9 per cent. carbon steel, however, this range is halved, since γ iron does not invert till about 700 deg. C. on cooling. From this it is argued that with increasing carbon contents there is more likelihood of some of the amorphous phase formed by the breakdown of the γ constituent being retained than in pure iron itself. Another factor also enters in which helps to promote the retention of the amorphous phase. Not only the iron, but also the iron carbide has to be considered. When the austenite breaks down, the carbide molecules are regarded as remaining "closely intermingled with those of the α iron." Before the amorphous material can recrystallise two different kinds of molecules have to segregate, those of iron and its carbide; this segregation must be a slow process in an undercooled viscous mass, and rapid cooling is regarded as allowing the minimum temperature of crystallisation to be passed before it has had time to take place.

Benedicks has shown that pressure aids the retention of the austenitic condition in steels. The change from the crystalline to the amorphous state in metals is in practically all cases accompanied by an increase in volume, γ iron is denser than α iron, and therefore even denser than amorphous α iron. Accordingly, Humfrey argues that after the formation of a certain amount of amorphous material, the pressure set up will be sufficient to retain some of the austenite in the unchanged condition.

According to Humfrey, then, the particular structure known as martensite is due to two constituents: (1) γ iron (austenite), (2) "an amorphous solution of α iron and carbide"; the form in which the two constituents occur being due to the tendency of the austenite crystals to break up along their gliding planes. It will be seen, therefore, that the conclusion reached by Humfrey is almost identical with that arrived at by Professor Edwards and myself, but that the actual mechanism of the change is different. As to whether on passing from one allotropic form to another it is necessary to assume the existence of an intermediate amorphous state, as postulated by Humfrey, it is not necessary for my present purpose to discuss. It may be pointed out, however, that the passage from the crystalline to the amorphous condition involves the absorption of energy, and Humfrey has not explained how that energy can be supplied from the interior of a slowly-cooling mass of material, and to render the theory complete in this respect an explanation must be forthcoming. On the other hand, when, as Professor Edwards and I have supposed, both slipping and perhaps twinning of the austenite crystals occurs as a result of the quenching of stresses, energy is absorbed, and may be stored up in the amorphous layers.

Within the limits of this lecture it has not been possible to consider anything like the whole of the evidence which may be brought to bear on the problem of the cause of the hardening of steel by quenching. In particular, the evidence which is furnished by the behaviour of alloy steels, specially those containing nickel or manganese, or both, has enabled the conditions intermediate between austenite on the one hand, and pearlite on the other, to be studied in a more systematic and comprehensive way than is possible with pure carbon steels. Moreover, the discovery and widespread use of the so-called high-speed cutting tools, all of them alloy steels, has widened the scope of the problem to an extent which could not have been realised as recently as twenty years ago. It will be observed that the three modern theories, of which some account has been given, present considerable resemblance to one another, in spite of certain differences which are obvious on the surface. The theories of Humfrey and Edwards and myself attribute hardening to the existence of a hard amorphous constituent in the steel. McCance does not go so far as this, but regards interstrain as the cause of hardness, a condition which I think it is fair to describe, as occupying an intermediate position between crystalline and amorphous materials. Perhaps at no very distant date McCance will develop a theory of interstrain action.

The acute differences which divided sharply the allotropists and the carbonists find no counterpart in the schools of thought of to-day. Indeed, it is interesting to reflect for one moment on the position of the allotropic theory of Osmond, in the light of the most modern view on the subject. According to these, M. Osmond was correct in attributing hardness to something—stated in its most general terms—intermediate between crystalline γ and crystalline α iron. The view that this intermediate something is a crystalline β iron such as he supposed has not been completely abandoned, but is not held by many workers to-day. This conception has given place to the inter-strained iron of McCance and the amorphous iron and iron-carbide complex of Humfrey, Edwards and myself. The important influence exerted by carbon, insisted upon by the carbonists, is fully recognised in the modern theories described. Speaking with the ampler knowledge of to-day one may summarise the position by saying that the older theories, tested and to some extent corrected by this, have contributed to a broader view of the matter, in which their apparent differences have been put into their proper proportion and the elements of truth they contained incorporated into other theories which for the time being are more in accord with such knowledge. That these in their turn are likely to be modified and amplified by the advance of knowledge I should be the first to admit.

CATALOGUES.

Motor Chassis.—Victor Motors, Limited, Temple Chambers, Temple-avenue, E.C. 4, send a catalogue of U.S.A.-made chassis for commercial vans, wagons, tractors, &c. The standard sizes are 1 ton, 25 cwt. to 30 cwt., 2½ tons, 4 tons, and 5 tons to 6 tons. These are all with petrol engines.

Lock Nut.—A pamphlet of 32 pages, issued by Vislock, Limited, 3, St. Bride's House, Salisbury-square, E.C. 4, shows that their lock nut is coming into general use for many machines and implements, especially those subject to severe vibration. The "Vislock" embodies in one nut the principle of the two separate nuts tightened against each other.

Wrought Iron.—Some years ago there was a revival of the controversy as to the merits of wrought-iron in comparison with mild steel, especially for "shock" tackle such as chains, hooks, coupling links and rings, and certain bolts. It is interesting, therefore, to receive an American catalogue, from the Mill and Mine Supply Company, 317, First Avenue South, Seattle, eulogising a "special refined long-fibre iron for rings, links, bolts, cold shuts or special places." A list is also given of "iron-steel" manufactures, including bolts, nuts, hammers and hacksaw blades.

Acetylene Lamps.—Fallolight, Limited, 27, Noel-street, Wardour-street, W., send an interesting catalogue of their lamps for hand carrying, motor cycles and cars, mines, searchlights and signalling, &c. The gas flame plays into a ball, or "pastille" making it incandescent, but emitting light from one side only. A lamp can be quickly adjusted to throw a far-reaching narrow beam or a short-distance flood of light. It is claimed that only half the gas is consumed as compared with the average acetylene burner, and that with equal gas consumption the light has eight times the efficiency.

Welded Ships.—A catalogue giving some precise information about electric welding as applied to ship construction comes from the Quasi-Arc Company, Limited, 3, Laurence Pountney Hill, E.C. 4. Line drawings of butt, lap, flat and angle welds are shown with the results of tests; also a sulphur print of the grain structure of a test bar welded end to end after an alternating test of 200,000 movements through 20 deg., 10 deg. on each side of the vertical. In July last one ship entirely welded, instead of riveted, was launched in this country, and Lloyd's Register has accepted the process.

Concrete Reinforcements.—A bound catalogue of 172 pages, giving a large amount of useful information about reinforced concrete, comes from the British Reinforced Concrete Engineering Company, Limited. Trafford Park, Manchester, and 36, Lime-street, London. The dimensions, sections, material and placing of the reinforcement is fully dealt with and a mass of general information added. The writing is clear in style, the arrangement good and a full index added. The book will be very useful to engineers and builders. This firm also send a copy, No. 6, of a useful little periodical entitled "Floor and Slab Reinforcement."

Electric Lifting Gear.—An interesting series of electric lifting and travelling appliances is shown in a catalogue from Messrs. S. H. Heywood and Co., Limited, Stockport. Generally the motor, pulley block and travelling gear are in a compact unit to fit the lower flanges of a girder as runway, sometimes the upper surface of the girder. The control is from the ground by chains and cords. These are made to work in all manner of awkward places, indoors and out. Some travel on a single girder mounted on trestle supports quite a long distance in the open air. The lifting and carrying power is generally ¼ ton to 3 tons and up to 6 tons. In some cases the travel is by hand power. The catalogue represents a great diversity of applications of this type of gear.

High-Speed Vertical Steam Engines.—A catalogue illustrating two series of these engines, simple and compound, comes from Messrs. Robey and Co., Limited, Lincoln. Both are made in open and enclosed types, the latter for very high speeds. Used chiefly for dynamo driving on ships, the designs secure compactness and flexibility of output. The simple engine is made in 12 standard sizes, with cylinders from 3¼ in. diameter by 3 in. stroke to 14½ in. diameter by 14 in. stroke—in all cases the diameter of the cylinder is ½ in. greater than the stroke. The compounds are about the same for the high-pressure cylinder, and a slightly longer stroke when the high-pressure cylinder is above 10 in. Tables give the brake horse-power at every 10 lb. rise of steam pressure from 40 lb. to 150 lb. These engines are produced in quantities by the finest machine tools and manufacturing methods to the highest point of finish and efficiency.

Winding Engines.—There is no task which should more impress men with a sense of duty than that of designing and making winding engines; and there is none better attended to. A catalogue from Messrs. Robey and Co., Limited, Lincoln, dealing with these engines alone, might be used by an imaginative man as the basis of a lecture to miners, which would show them that they are not in all respects the despised class which they imagine themselves to be. The dangers in the working of winding engines and gear are many, and they are discussed in the catalogue with a refreshing keenness of interest. These dangers are mainly overwinding, accidentally starting the engine in the wrong direction and overspeed either at stopping or at any point in the pit shaft. These, of course, are apart from the many dangers that would arise if any carelessness in construction or effort at cheapness were made. Main strength is lavishly provided everywhere, and all the safety devices are reduced to simple, strong mechanical forms. Compound engines in pairs, with drop valve gear, predominate, though simple engines in multiple are also used. These are sent to many parts of the world, forming one of the largest items in British machinery exports. The catalogue proves that while the firm can show a fine record in this work there is no such self-complacency as would dull their eagerness for further progress.

Locomotive Engines.—The "articulated" (not a happy name) locomotive recalls the successive problems arising from the development of steam railway traction. More than thirty years ago engines and boilers were made of greater power than could be used on a rigid frame. The limit then was the grip of the driving wheels on the rails. Of course, an indefinite number of wheels could be fitted to a frame and driven coupled, but railway curves put a limit to the length of a rigid wheel base. In 1889 a French engineer, Anatole Mallet, designed and ran a railway locomotive of the "articulated" type which allowed a vastly greater development in power of boilers and engines on a single locomotive The type has been developed to the largest powers in the United States, where many locomotives with 16 driving wheels are in use, and in one type eight more driving wheels are placed under the tender, making 24 in all. This is effected by placing a compound hinge or "articulated joint" between each four pairs of wheels, so that the frame may swivel at this point both horizontally and vertically. The difficulty arises mainly in the steam pipes and valve gear because the engine remains a unit, or a pair of compound engines with one boiler, all under one main control. A booklet received from the Baldwin Locomotive Company, Philadelphia, U.S.A., explains all this in clear, simple terms, and presents illustrations and the main particulars of a considerable variety of Mallet articulated locomotives. These range from comparatively small 0-6-6-0 types built by the Baldwin Company for the Spanish and Japanese railways, to many 2-8-8-2 types used only on United States railways, and the exceptional 2-8-8-8-2 type used on the Erie, U.S.A., railroads. The booklet, "Record 91" is one of a series and affords extremely interesting reading to engineers, especially those who have sufficient experience to appreciate the great practical mechanical difficulties overcome by the Baldwin Company. It is well worthy of a place in every engineering library.

RAW MATERIAL IMPORTS.—The Board of Trade have notified that general licences have now been issued to the Customs which, together with the general licences already in existence, will exempt all raw materials from the operation of the prohibitions of import. The following are among the raw materials which have from time to time been under prohibition and are now free:—Antimony ore; diatomite or infusorial earth; gum copal; gum kauri; jute; stones and slates (including sawn and hewn, but not dressed); wood and timber, hewn and sawn, planed and dressed of all kinds, hardwoods and sleepers (but not including staves, pit-props and pitwood). Any inquiry arising out of a doubt whether an article is to be regarded as a raw material or a semi-manufactured article, should be addressed to the Department of Import Restrictions, 22, Carlisle-place, London, S.W. 1.

GERMAN ECONOMIC OFFENSIVE IN SPAIN.—The *Mundo* for January 1 laments that owing to lack of foresight on the part of Spain, the control of her industry and commerce is not in her own hands, and that she is therefore now in the same position as in 1914. This enables victors and vanquished to cast their eyes on Spain as a field for their industrial, commercial and financial activities which will compensate them for their losses in the war. The Allies have been less alert than they should have been, and just as Germany during the war was beforehand in capturing public opinion by the acquisition of organs of publicity and in creating a fictitious atmosphere, which still exists, so now have German financial and mercantile houses forestalled their rivals in establishing business connections in Spain. M. Viellard, a manufacturer of Belport, after a visit to Spain, is of this opinion, and has recorded his impressions as follows: "Germany, he writes, has staked out her claims beyond the Pyrenees, in order to direct and profit by Spain's economic awakening. Her plans, skilfully worked out and strongly supported by capital, lead us to assume that our enemy is preparing in as complete a manner as possible, to take a hand in the principal Spanish enterprises. All nations, he continues, particularly Germany, have noted the promise of industrial and agricultural revival in Spain. At present some hundred thousand Germans in the country, powerfully supported, not only by their Government, but by their financiers (German and Austrian banks have been founded in Madrid with this object), are seeking to acquire properties and to gain possession of the majority of Spanish enterprises. In fact, our enemies evidently hope to convert Spain into an economic colony. Spain possesses immense wealth in her soil and subsoil, which, however, requires technical exploitation. This wealth may prove a considerable industrial resource to France after the war, but energetic measures must be taken to prevent the enemy from becoming the masters of the industrial Spain which is about to arise. Otherwise we shall be caught in an economic vice, and, in addition, the gates of South America will be closed to us." The *Mundo* agrees with M. Viellard's remarks, and laments that the national inertia has reduced Spain to the condition of a satellite revolving in the orbit of foreign bodies.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Name, &c., of the Communicators are given in italics.

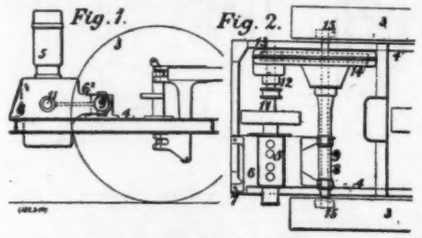
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

AGRICULTURAL APPLIANCES.

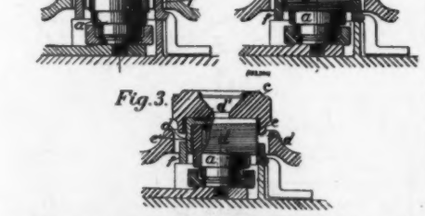
122,247. The Boon Tractors, Limited, Warwick, and J. D. Boon, Warwick. Tractors. (2 *Figs.*) January 17, 1918.—The invention consists of a tractor of the two wheel type, wherein the forward part of the engine is mounted upon the frame of the tractor and the rear part of the engine is mounted upon the casing of the differential shaft. 3 are the wheels of the tractor, and mounted between them is a horizontal rectangular frame 4 mounted upon the axle of the wheel 3. The engine 5 is mounted upon a framing 6, the forward part of the framing 6 being bolted to the tractor frame 4; the rear part of the engine framing 6 is mounted on the casing 8 of the differential shaft 9, flanges being formed on the differential casing between which extensions of the engine framing 6 are located, the differential casing 8 being mounted upon the tractor frame 4. The crank-shaft 11 of the engine is coupled to the pinion shaft 12, and



mounted on the shaft 12 is a pinion 13 gearing with the toothed wheel 14 connected to the differential shaft 9, the differential shaft being provided with driving pinions 15 which mesh with the toothed sections of the wheels 3 for transmitting the driving motion of the engine to the wheels 3. This arrangement and disposition of the engine 5 and differential casing 8 ensure that the axis of the crank-shaft 11 is in alignment with the axis of the speed pinion shaft 12, and that the axis of the differential shaft 9 is in alignment with the axis of the bearing of the extensions of the framing upon the differential casing 8. By this arrangement the engine and the differential casing constitute substantially one unit upon the tractor frame 4, with apparent advantages in erection and running as opposed to an engine and a differential gear-casing each separately mounted upon the tractor frame. (*Accepted January* 29, 1919.)

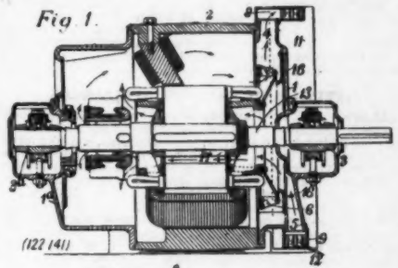
ELECTRICAL APPARATUS.

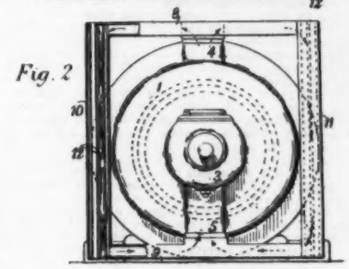
122,360. R. A. R. Bolton, Barnes, London. Electrical Fuses. (3 *Figs.*) July 5, 1918.—This invention relates more particularly to non-interchangeable fuses in which the fuse body or cartridge is held in position by a screw cap. The present invention comprises an arrangement in which one end or pole of the fuse or cartridge, together with its projecting tube or sheath, are made in one piece of metal, in the form of a hollow screw-threaded cup or shell, provided with the screw thread which otherwise would be formed on the separate cup or liner of the cap in the ordinary construction. *a* is the body or cartridge of the fuse, which is of ordinary construction, *b* being its protecting tube or sheath and *c* its screw cap or knob. *d* is the cup-shaped screw-threaded liner above referred to, which forms the contact screw and is cemented into the cap *c*, as shown at *e*. *f* is the fixed ring contact

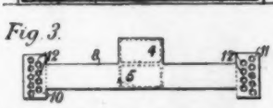


or socket which is screw-threaded to receive the liner or contact *d*. In the ordinary arrangement shown in Fig. 1, the electrical connection at the top between the parts *b* and *d* is merely set up by the pressure. With the improved arrangement shown in Figs. 2 and 3, however, since the parts *b* and *d* are formed in one, there is an absolute connection from the fuse wire to the screw contact inside the fixed ring or socket *f*. The screw contact *d*, in Fig. 2, is made thick enough to form the protecting tube around the fuse, and is secured thereto by cement in the annular space *e*, whilst the cap *c* may be secured thereto by cement *e*. The fuse wire is soldered or sweated to the top of the screwed shell *d*, and is further secured by a metal disc *d*1 also soldered in place in a recess in the top of *d*. The current is thus carried direct from the fuse wire to the screwed portion of the cap, and not as previously through a contact surface and the cap as well. (*Accepted January* 29, 1919.)

122,141. J. H. St. H. Mawdsley, Dursley. Dynamo Electric Machines. (3 *Figs.*) August 9, 1918.—This invention relates to dynamo-electric machines of the totally-enclosed type provided, external to the machine, with heat dissipating means, comprising a radiator through which the air contained within the machine is caused to circulate by a fan. In dynamo-electric machines of the type mentioned, heat dissipating means, in accordance with this invention, comprise, in combination, a casing closing the pulley end of the machine, situated between the bearing and armature and yoke, and having ports disposed diametrically thereof and above and below the bearing, a fan situated between the casing and armature drawing and expelling air through said ports, and a radiator of bipartite construction, one part being on the one side and the other part on the opposite side of the bearing, said parts being connected at their ends with the ports in the casing. 1 is a member attached to the yoke 2 and forming a bracket for the bearing 3 at the pulley end of the machine. The member 1 is also such that it forms a casing closing the said end of the machine. The bearing 3*a* at the commutator end of the machine is also carried by a bracket 1*a*, by which the complete closure of this end of the machine can be effected. The member or casing 1 has two ports 4, 5, which are diametrically disposed and are arranged to come above and below the bearing 3. 6 is a fan; this fan is, in the construction shown, mounted directly on the armature 7; it may, however, be mounted directly on the armature shaft 13. Whichever mode of mounting is adopted, the construction of the fan



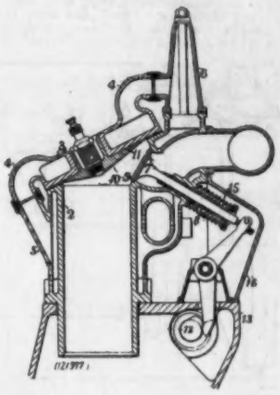




is such that it prevents almost wholly direct connection between the ports 4, 5, and divides the space enclosed by the casing 1 into two portions, the one and central portion being in connection with the port 5 and the other and outer or annular portion being in connection with the port 4; 16 is an annular shield mounted on the interior of the casing 1, adjacent the fan 6, with its inner edges bent inwardly and extending almost into contact with the body of the fan. 8, 9 are air ducts; these air ducts are carried by the casing 1 and are disposed horizontally, the one above and the other below the bearing 3. The duct 8 is midway, or about midway, of its length in connection with the port 4 and the duct 9 is similarly in connection with the port 5. At their outer ends, the air ducts are connected together by vertical air ducts 10, 11, each of which contains a plurality of tubes 12, whose upper and lower ends are secured in the upper and lower walls of the air ducts 8, 9, respectively, and whose interiors are in connection with the atmosphere. The members 10, 12 and 11, 12 form the two parts of the radiator. The air enclosed within the machine and the air ducts 8, 9, 10, 11 is caused to circulate by the fan 6. The air passes from the air ducts 8, 10, 11, 12 through the port 5 to the central portion of the casing, and thence through the centre of the fan 6, to and through longitudinal slots 17 in the armature 7, to the other end of the machine, the air returns around the field coils and poles to the outer and annular portion of the casing and is impelled by the fan 6 through the port 4 to the air duct 8. The heated air is cooled in its passage through the bipartite radiator 10, 11, by the atmosphere which, through convection, is caused to flow upward through the tubes 12. (*Accepted January* 22, 1919.)

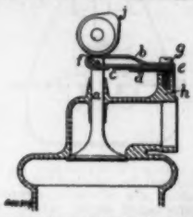
GAS ENGINES, PRODUCERS, HOLDERS, &c.

121,977. S. S. Guy, Finchfield, Wolverhampton. Internal-Combustion Engines. (1 *Fig.*) October 8, 1917.—An internal combustion engine embodying this invention is characterised in that the valves are all arranged at one side of the cylinder or cylinders and have their axes inclined with respect to the axis of the cylinder or cylinders at such an angle as to leave the cylinder head free to be removed without involving any interference with or dismantling of the valve mechanism. 2 represents the engine cylinder and 3 the removable cylinder head or cover which takes an oblique seating upon the top of the cylinder and may conveniently take the form of a hollow water-cooled casting provided with elbow connections 4 for establishing connection between the cylinder jacket 5 on the one hand and the top water pipe 6 on the other. The water connections to the cylinder head might alternatively be made as ports in the joint between the cylinder and head. The valves 7, which are of the poppet type, are all arranged at the opposite side of the cylinder to the cylinder head and have their stems 8 inclined in a downward direction at an angle thereto of approximately 60 deg. in planes containing the cylinder axis. At or about this angle the valve seats 9, combustion chamber 10 and piston (not shown) are particularly accessible when the cylinder head is removed and the valves and piston can also be withdrawn through the opening made by the removal of the head or cover without the necessity for dismantling the valve mechanism, whilst at the same time no internal pockets in the sense commonly understood are formed in the combustion chamber. If desired, the cylinder head 3 may, as shown, be provided with a compression plate 11 for the purpose of reducing the volume of the combustion chamber unswept by the piston. In this arrangement, the camshaft 12 is preferably arranged below the valves and journalled in bearings carried either by the cylinder casting or, as shown, by the crank-case 13 as found necessary or desirable. This construction also



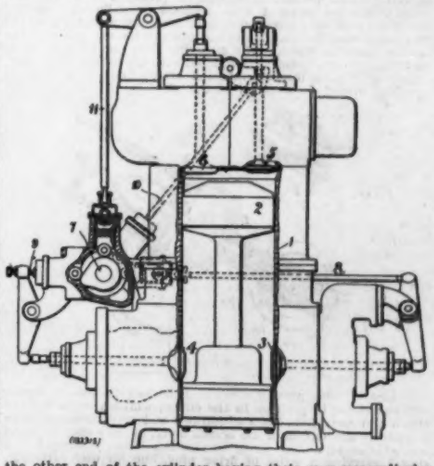
has the advantage that the valve rockers, valve stems 8 and springs 15 may be entirely enclosed in a dustproof and oiltight casing 16 bolted to the side of the engine and made readily attachable. (*Accepted January* 22, 1919.)

122,379. J. L. Norton, Aston, Birmingham, and Norton-Motors, Limited, Aston, Birmingham. Internal-Combustion Engines. (2 *Figs.*) September 24, 1918.—This invention relates to mechanically-operated valves of internal-combustion engines in which the valve is operated against the action of a spring by the pressure of a cam applied to the valve stem in the case of overhead valves, or to the tappet rod in other mechanically-operated valves. In accordance with the invention, the laminated spring is arranged adjacent to the end of the valve



stem or tappet rod, and one of the laminæ of the spring is arranged to pass over the end of the stem or rod to form the surface against which the valve bears. *a* is the valve stem, *b* is the slotted lamina passing over the end of the stem *a* and bent back to engage the stem below the other lamina *c* which bears against the pin *f* holding the valve in position. *d* and *e* are two other laminæ of the spring to add to its strength; *j* shows the cam bearing against the top lamina *b* of the spring. The spring laminæ are held in position by a screw on to the projection *h*. (*Accepted January* 29, 1919.)

122,315. K. Cox, Southsea. Internal-Combustion Engines. (1 *Fig.*) March 7, 1918.—This invention relates to an internal-combustion engine having a double-acting cylinder with inlet and exhaust valves for each end thereof operated by separate valve rods. In accordance with this invention, all of the valves are actuated from a single camshaft and the axes of the inlet and exhaust valves at one end of the cylinder are parallel with the cylinder axis, the inlet and exhaust valves at



the other end of the cylinder having their axes perpendicular thereto. The double-acting cylinder 1 is provided with a piston 2, and has at its lower end an inlet valve 3 and exhaust valve 4 arranged on a common horizontal axis, and at the upper end an inlet valve 5 and exhaust valve 6 having vertical axes. All the four valves are actuated from a single camshaft 7 by separate operating rods 8, 9, 10, 11, respectively. (*Accepted January* 29, 1919.)

122,262. T. B. Murray, Scotstoun, and Albion Motor Car Company, Limited, Scotstoun. Internal-Combustion Engines. (3 *Figs.*) January 23, 1918.—In an engine made according to the invention, the combustion space arranged in

the detachable cylinder head is of conoidal or ungulate form. The inlet and exhaust valves are arranged side by side at one side of the combustion space, and are of such area and are placed with their axes at such

Fig. 1.

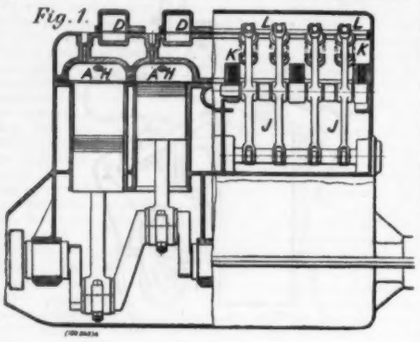
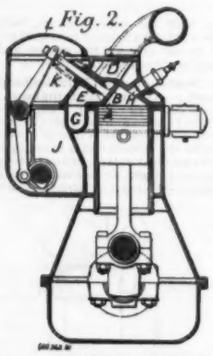


Fig. 2.



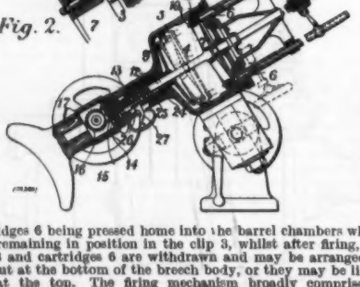
an inclination to the cylinder axis that they may be withdrawn diagonally inwards through the detached head. The passages D from the exhaust valves pass substantially through the top of the head and at right angles to the valves. The inlet-valve passages E communicate with a manifold channel G formed in the upper part of the cylinder casting and closed by the head casting. The sparking plug apertures H are formed diametrically opposite the valves and thus may be well jacketed. A lateral pocket J is formed in the cylinder casting to receive valve mechanism, and this corresponds and makes joint with a similar lateral pocket K in the detachable head. On the top of this latter is a door L giving access to the valves and their parts. (*Accepted January* 22, 1919.)

GUNS AND EXPLOSIVES.

122,386. J. J. B. Arter, Greeta, juxta Birmingham, and The James Cycle Company, Limited, Greeta, juxta Birmingham. Multi-Barrel Guns. (2 *Figs.*) November 16, 1917.—The invention relates to the extracting and firing mechanism of multi-barrel machine guns and refers to that class of firing mechanism in which the cartridges are held in a clip during insertion, discharge and ejection, and a breech closing member carrying spring-pressed firing pins is provided in conjunction with a hammer adapted when released to strike and operate the firing pins, said breech-closing member being adapted to hold the clip during the charging of the gun and the extraction of the empty cartridge cases. The clip ring 3 is adapted to carry cartridges 6 corresponding in number with the barrels of the gun, this ring 3 being inserted into the breech body 4 through an opening formed by removal of the plate 5, the whole of the

Fig. 2.

Fig. 1.



cartridges 6 being pressed home into the barrel chambers whilst still remaining in position in the clip 3, whilst after firing, the clip 3 and cartridges 6 are withdrawn and may be arranged to fall out at the bottom of the breech body, or they may be lifted out at the top. The firing mechanism broadly comprises a ring 7 carrying a series of firing pins, one for each cartridge, together with a hammer 9 which simultaneously engages all the firing pins, the ring 7 also carrying means for gripping the clip 3, and thus withdrawing the cartridges 6 from the barrels. The ring 7 contains a series of tappets 10, spring receded, and corresponding in position with the gun barrels 2, the ring 7 being carried by a sliding shaft 12, the rear end of which engages with a nut 14 held against axial movement and carrying bevel gear teeth 15 which are engaged by similar teeth 16 on a short shaft controlled by a hand wheel 17 so arranged that rotation of the hand wheel in the one direction will press the cartridges into position in the barrel chambers at the same time putting the tappets into position for firing, whilst rotation in the opposite direction will withdraw the cartridges, automatically releasing them and permitting others to be inserted in their place. The means for withdrawing the cartridges comprises a plurality of fingers 18 pivoted upon the periphery of the ring 7 and having hooked extremities which engage with the outer periphery of the ring 3 which forms the clip for carrying the cartridges. These hooked fingers 18 are pressed outwardly by springs 21 against the interior wall of the breech body 4, this interior being, however, of two diameters, the diameter at the rear being greater than at the forward end, so that when the ring 7 is retracted to the rear end of the breech body the fingers 18 will move outwardly and release the cartridge clip 3, whilst when the ring 7 is moved forwardly the fingers 18 are pressed inwardly and will grip the clip 3 if the clip has been inserted in a suitable position. The clip 3 is thus moved forwardly so as to bring the cartridges 6 into place simultaneously with the ring 7, whilst, after firing, the return movement of the ring 7 takes with it the clip 3 and cartridges 6, which are released when they have reached a position where the large diameter permits the fingers 18 to open. The hammer comprises a disc 9 which is adapted to simultaneously engage with the whole of the tappets 10. This hammer disc 9 is carried by a hollow shaft 24 disposed around the shaft 12 which carries the ring 7, and when released the hammer 9 is advanced by a strong spring 25 so as to simultaneously strike the whole of the tappets 10. The hammer 9 is normally held in its receded position by a projection 26 which engages with a spring trigger 27, the release of which serves to release the hammer. After firing, the hammer 9 is receded by withdrawal of the ring 7, by means of the hand wheel 17 and is automatically locked in its receded position when it engages with the trigger 27. (*Accepted January* 29, 1919.)

LIFTING AND HAULING APPLIANCES.

122,389. F. L. Rapson, Liverpool. Lifting Jacks. (8 *Figs.*) December 17, 1917.—According to the present invention, the lifting jack comprises, in combination, a casing formed with an enlarged base, a sleeve slidably mounted in said casing, a nut formed or provided on said sleeve, a rod rotatably mounted in said sleeve, anti-friction balls arranged between the rod and nut, a channel or duct for the circulation of the balls, a bevel wheel secured on the lower end of the rod meshing with another bevel wheel secured on an angularly-arranged transverse shaft rotatably mounted in the base of the casing, a square or other shaped hole in said shaft for the reception of a detachable operating handle, a ratchet wheel on the shaft and a pawl pivoted on the casing to engage with said ratchet wheel. The lifting jack comprises a substantially cylindrical casing 1 in which is slidably mounted the sleeve member 2, having at its lower end an internally screw-threaded nut 3. Within the sleeve member 2 and nut 3 is rotatably mounted a rod 4 cut with a deep square thread to co-operate with the thread cut in the nut 3. A groove 5 is cut on the upper side of the thread on the rod 4, and a similar co-operating groove 6 is cut in the under side of the thread in the nut 3. Within the grooves 5 and 6 is disposed a number of anti-friction balls 7. The outer ends of the groove 6 in the nut 3 are connected by a through channel 8 to provide for the circulation of the balls 7. It will be obvious that where the balls 7 enter or leave the nut 3 the ball races or grooves are inclined and cut deeper to permit the balls 7 to enter or leave the channel 8. The balls 7 in the other portion of the ball race may be sunk above their centres, preferably to a depth of about three-quarters of their size. If desired, rollers may be provided in place of balls between the co-operating faces. The sleeve 2 is preferably provided with a slot 9 to receive the inner projecting end of a

Fig. 1.

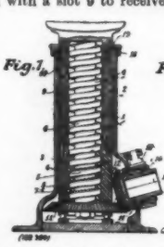
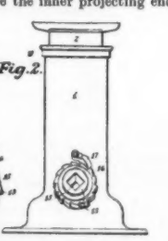


Fig. 2.



screw 10 threaded into the casing 1 to guide the vertically movable portion of the jack. A bevel wheel 11 is secured on the lower end of the rod 4, which is adapted to be rotated by another bevel wheel 12 secured on an angularly-arranged transverse shaft 13. This shaft 13 is rotatably mounted in the base of the casing 1, and a suitable thrust bearing 14 is provided between the casing 1 and the said bevel wheel 12. The shaft 13 is formed with a squared or other suitably-shaped hole or recess 15 for the reception of the squared or other suitably-shaped end of an operating handle or the like. This handle is preferably of T shape, and when of considerable length may be constructed in any suitable manner, to fold up neatly. On the outer end of the shaft 13 is secured a ratchet wheel 16 and a pawl 17 is pivoted on the casing 1 to engage with the said ratchet wheel 16 so that the jack can be raised and the lowering prevented until the said pawl 17 is placed out of engagement. The jack is preferably lowered by turning the detachable handle in the opposite direction when the pawl 17 is disengaged. The casing 1 is rendered dust-proof by screwing on the upper end thereof an annular cover plate 18, a suitable washer 19 being disposed between the upper end of the casing 1 and the cover plate 18. In operation the jack is placed under the part it is desired to raise. The jack is operated by inserting the square end of the handle in the squared recess 15 in the spindle 13, and rotating the same. This rotation will turn the rod or shaft 4 through the medium of the bevel wheels 12 and raise the sleeve 2 and the end of the axle and the adjacent wheel from the ground, so that repairs can be executed. The part may be lowered preferably automatically by raising the pawl 17 out of engagement with the ratchet wheel 16, or by rotating the handle in the opposite direction, as will be well understood. (*Accepted January* 29, 1919.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

122,272. S. J. Ross, London. Lock-Nut Devices. (3 *Figs.*) January 23, 1918.—This invention has reference to lock-nut devices. According to this invention, the device is so constructed that not only is an eccentric grip action obtained

Fig. 1.

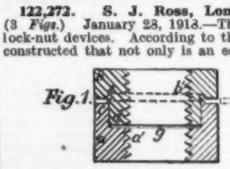
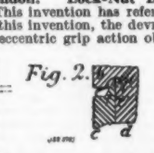
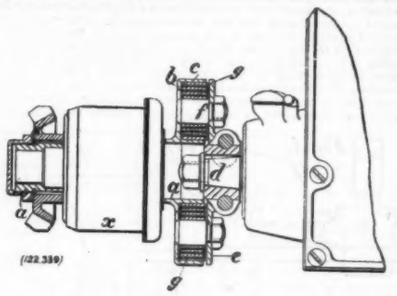


Fig. 2.



but the ordinary locking or jamming action of the back-nut against the main nut is also effectually set up. Thus the two locking actions supplement one another, giving a double locking action. *a*, *b* are, respectively, the main nut and the back nut or jamb nut. *a*1, *b*1 are, respectively, their screw-threaded bores, which are eccentric to the nuts themselves. *c* and *d* are the socket and spigot parts by which the binding or gripping action is produced. These parts are concentric with the nut itself and therefore the bores *a*1, *b*1 are eccentric to them also. When the device is screwed on a bolt, this eccentricity causes *d* to bind in the known manner in *c* when the back nut *b* is turned separately in relation to *a*. *e* is a groove or recess formed around the neck of the part *d*, to receive the bent-over edge of a wedgelike lip *f* round the mouth of the socket *c*. This arrangement prevents the nuts becoming detached from one another, but allows them to turn freely in relation to each other, and also allows the spigot to move in and out of the socket slightly, the amount of play or lost motion being equal to the gap *g* between *a*1 and *b*1. The groove *e* may be formed in a lathe with an undercutting tool. The lip *f* is also machined in a lathe. (*Accepted January* 29, 1919.)

122,339. The Siddeley-Deasy Motor Car Company, Limited, Coventry, and F. R. Smith, Coventry. Elastic Couplings for Shafts. (4 *Figs.*) April 17, 1918.—This invention relates to elastic couplings for shafts arranged in axial alignment. On to the end of the driving shaft *a*—which in the construction shown is hollow, and is mounted to run in the bearing *x*—adjacent to the driven shaft is a plate *b* having two diametrically opposed recesses *c*, *c* of cylindrical shape. On the end of the driven shaft *d*—which in the construction shown is the armature shaft of a magneto—adjacent to the driving shaft is fixed a plate *e* on which are mounted in diametrically opposed positions, two pins *f*, *f*, the centres of said pins being at the same distance from the centre of the shaft *d* as the centres of the recesses *c*, *c* are from the centre of the shaft *a*, so that when the



parts are assembled the pins lie centrally or approximately so within said recesses. Fitting with the recesses *c* are coiled springs *g* of the clock type with which the pins *f* engage, the exterior diameter of the springs being slightly more than the diameter of the recesses *c*, so that they are slightly contracted when placed in position in the recesses, and the internal diameter of said springs is slightly less than the diameter of the pins *f*, so that they are slightly expanded when said pins are placed within them. To facilitate assembling, the free ends of the pins *f* are slightly tapered or bevelled to facilitate their engagement with the springs. To allow free movement—within limits—between the two plates *b* and *e*, holes *b*1 are provided in the plate *b* at the bottom of the recesses *c* for the ends of the pins *f* to play in, said holes being of a larger diameter than that of the pins. (*Accepted January* 29, 1919.)

MINING, METALLURGY AND METAL WORKING.

122,034. C. W. Kayser, Sheffield, and J. E. Robinson, Sheffield. Electric Furnaces. (7 *Figs.*) January 12, 1918.—This invention relates to water-cooled electrode holders for electric furnaces. According to this invention, the framework or entablature *a* is formed with a rearward extension *a*1, to which are attached arms *b*, *b* connecting it to the carriage on one of the furnace masts. The entablature *a* has a cored out chamber or chambers *a*2, through which water circulates, and has a circular opening *a*3 in its lower part, which is slightly larger than the diameter of the electrode which passes through it. Adjustable gripping contacts *c*, *c*1 and *c*2, curved to a suitable radius, are

Fig. 1.

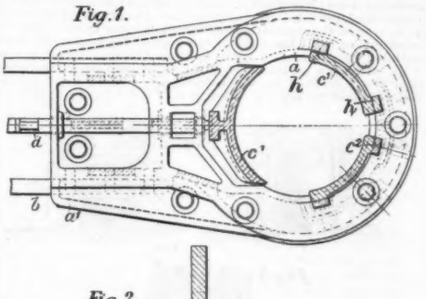
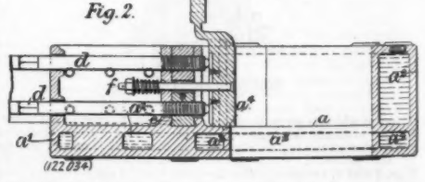


Fig. 2.



inserted above the opening *a*3 and rest upon a ledge *a*4 formed above said opening. When the electrode is in position, the contacts are advanced up to and firmly grip the same. The gripping contact *c* is actuated by screws *d*, *d* engaging in nuts *e*, *e*. A guide rod *f* keeps the contact *c* in alignment when being moved, and the spring *g*, on the rod, withdraws the contact when the pressure of the screws *d*, *d* is relaxed. The gripping contacts *c*1, *c*2 are adjusted by means of packing pieces *h*, lying within recesses in the entablature *a* and which packing pieces can be readily removed and replaced by others of different thicknesses or two or more packing pieces may be used at one point. The contacts *c*1, *c*2 each have a guide pin. (*Accepted January* 22, 1919.)